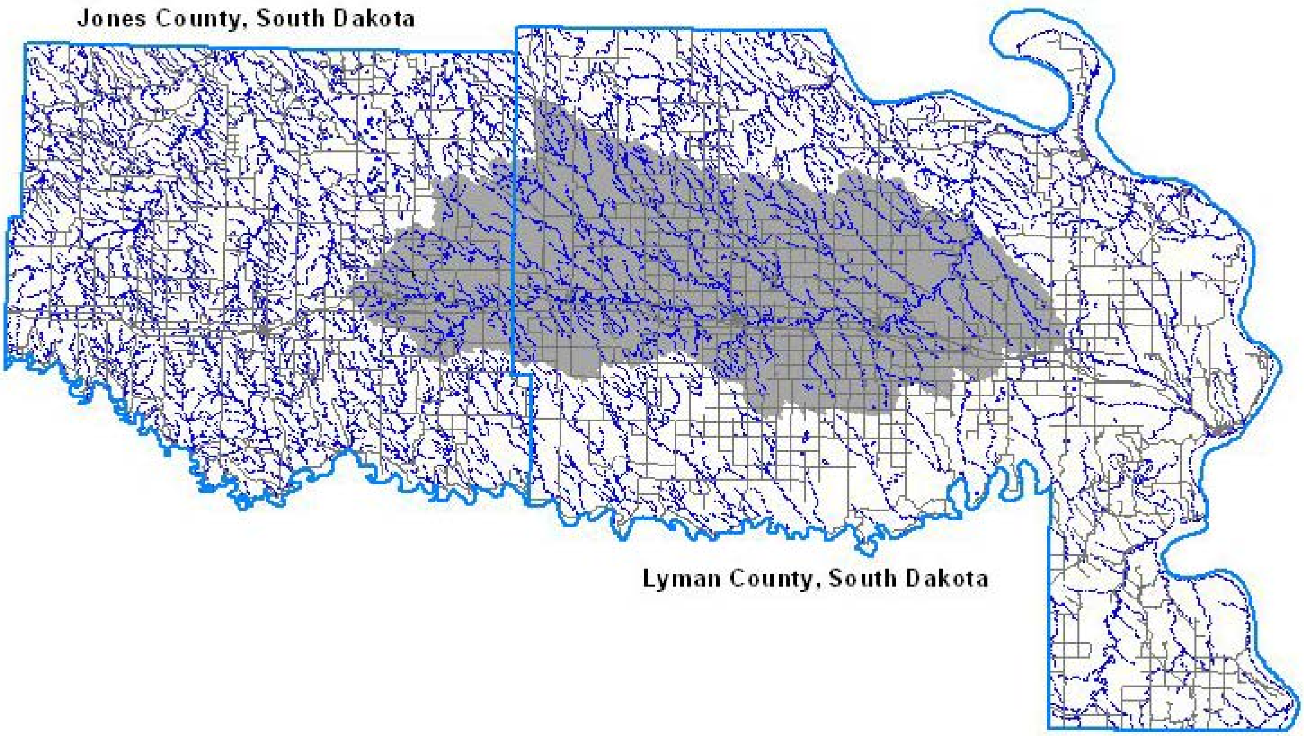
PHASE I
WATERSHED ASSESSMENT FINAL REPORT
AND TMDL

MEDICINE CREEK
LYMAN AND JONES COUNTIES, SOUTH DAKOTA



South Dakota Water Resource Assistance Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Steven M. Printer, Secretary

AUGUST 2005

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South Dakota Water Resource Assistance Program
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Steven M. Pirner, Secretary

Prepared By

Robert L. Smith, Environmental Program Scientist

State of South Dakota
M. Michael Rounds, Governor

August 2005

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM ASSESSMENT/PLANNING PROJECT FINAL REPORT

MEDICINE CREEK WATERSHED ASSESSMENT AND TMDL

by:
Robert L. Smith

Project Sponsor:
American Creek Conservation District

July 2005

This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

EPA Grant # C9998185-00

Executive Summary

Project Title: Medicine Creek Watershed Assessment Project

Project Start Date: April 1, 2000	**Project Completion Date:** December 31, 2001
Funding:	**Total Budget:** $ 169,660
Total EPA Budget:	$ 101,796
Total Expenditures of EPA Funds:	$ 101,796
Total Section 319 Match Accrued:	$ 75,238.38
Budget Revisions:	No Revisions
Total Expenditures:	$ 177,034.38

Summary of Accomplishments

Medicine Creek is listed on the 2004 Integrated Report (SD DENR 2004) for conductivity and total dissolved solids. The Medicine Creek drains a watershed of approximately 157,860 ha (390,072 acres) in Lyman and Jones Counties, South Dakota. Three recreational lakes (Fate Dam, Brakke Dam and Byre Lake) are within the Medicine Creek watershed. The American Creek Conservation District (ACCD) located in Kennebec, South Dakota sponsored this project.

A total of 16 tributary sites were sampled comprising 119 routine and 25 QA/QC samples were collected by the sponsor from May 2000 through May 2001. Project and water quality monitoring data indicated surface water quality standards were exceeded during this project. Water quality and hydrologic data from the Medicine Creek watershed were modeled using the FLUX model. Assessment data show conductivity and total dissolved solids parameters violated surface water quality standards and were attributed to natural conditions in this watershed due to the geologic makeup of the basin, exclusively during low flow conditions. Given that conductivity and total dissolved solids exceedance always occurred at flows below one cubic foot per second, South Dakota Department of Environment and Natural Resources is considering incorporating the beneficial uses of fish and wildlife propagation, recreation and stock watering waters and irrigation waters (categories 9 and 10, respectively) to section 74:51:01:30. This section describes the minimum flow rates, either (7Q5) or 1.0 cubic foot per second, whichever is greater, below which water quality criteria is not applicable. Upon approval, previous violations water quality standards for conductivity and total dissolved solids occurring at low flows due to geological composition will not apply. This will effectively remove conductivity and total dissolved solids as parameters of concern in Medicine Creek.

During the assessment, two additional water quality parameters (total suspended solids and fecal coliform) violated South Dakota surface water quality standards and were in need of TMDLs (Total Maximum Daily Load). Fate Dam, Brakke Dam and Byre Lake have also been assessed and have EPA approved total phosphorus TMDLs.

Loading and reduction data were used to determine appropriate (attainable) reduction potentials for TMDLs in Medicine Creek. Landuse and feedlot data from the watershed were also collected by the project sponsor for use in the AnnAGNPS model. The AnnAGNPS model was used to identify critical areas and priority ranking in the watershed for sediment erosion and nutrient runoff for targeting during implementation. AnnAGNPS was also used to estimate/model Best Management Practice (BMP) reductions in sediment and nutrient loads. Water quality loading (FLUX) and AnnAGNPS data were sufficient to develop TMDLs for total suspended solids and fecal coliform in Medicine Creek.

Attainable TSS load reduction percentages estimated by AnnAGNPS were modeled using the FLUX program to calculate the appropriate TSS load allocation for Medicine Creek. Because most violations occurred during high flow events, the realized modeled reduction percentage (20.1 percent) was greater than the initial modeled reduction (10 percent). The TSS TMDL for Medicine Creek is to reduce the current annual load allocation approximately 20.1 percent (20,164,594 kg/yr) producing a TSS TMDL of 20,172,490 kg/year.

AnnAGNPS feedlot model and SD DENR feedlot rating program also indicated an 18.3 percent reduction in average delivered fecal coliform (cfu/100 ml/animal) may be attainable in Medicine Creek. The fecal coliform TMDL for Medicine Creek was to reduce the calculated current fecal season load allocation to 3.79×10^{13} cfu/fecal season or approximately 18.3 percent producing a fecal coliform TMDL of 3.89×10^{13} cfu/fecal season (an approximate overall reduction of 16 percent) with an implicit MOS. The recommended overall fecal coliform reduction based on waste reduction from an estimated 1,793 animals will be needed to meet the TMDL.

Acknowledgements

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Medicine Creek and its watershed could not have been completed without their assistance.

US EPA Non-Point Source Program
Lyman County
Jones County
South Dakota Conservation Commission
South Dakota Association of Conservation Districts
American Creek Conservation District
Jones County Conservation District
Natural Resource Conservation Service – Lyman County
Natural Resource Conservation Service – Jones County
SD Department of Game, Fish and Parks
SD Department of Environment and Natural Resources – Water Rights Program
SD Department of Environment and Natural Resources – Drinking Water Program
SD Department of Environment and Natural Resources – Water Resources Assistance Program
Lower Brule Sioux Tribe
North Central RC&D

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Waterbody Type:	Stream
Pollutants:	Conductivity @ 25° C, TDS (Total Dissolved Solids), TSS (Total Suspended Solids) and Fecal Coliform Bacteria
Designated Uses:	Warmwater marginal fish life propagation, Limited contact recreation, Wildlife propagation and stock watering and Irrigation waters.
Size of Waterbody:	Medicine Creek - (390,072 acres).
Size of Watershed:	157,857 ha (390,072 acres), HUC Code: 10140104.
Water Quality Standards:	Numeric: Conductivity, TDS, TSS and Fecal Coliform Bacteria
Indicators:	Numeric standards exceedances in Conductivity, TDS, TSS and Fecal Coliform Bacteria
Analytical Approach:	Effects of nutrients and sediment loads from the watershed on Medicine Creek.

1.0 Introduction

Medicine Creek is located in the Northwestern Great Plains (43) ecoregion (Level III) in central South Dakota and is listed on the 2002 303(d) Impaired Waterbody List (SD DENR 2002) and the 2004 Integrated Report (SD DENR 2004) for conductivity and TDS (Total Dissolved Solids). Medicine Creek, (the study area) drains a watershed of approximately 157,860 ha (390,072 acres) from approximately Draper, South Dakota to the boundary of Lower Brule Sioux Reservation in Lyman County, South Dakota. The Creek then flows through the reservation and empties into the Missouri River in Lake Sharpe, Lyman County, South Dakota (Figure 1). This portion of Medicine Creek was not in the study area because the State of South Dakota has no jurisdiction on tribal ground and is considered Indian Country as defined in 18 U.S.C. 1151. The American Creek Conservation District (ACCD) located in Kennebec, South Dakota sponsored and supported this watershed assessment project.

This project is intended to be the initial phase of a watershed-wide restoration project. Water quality monitoring, stream gauging, stream channel and land use analysis were used to document the sources of impairment to Medicine Creek. Feasible alternatives for watershed restoration are presented in this final report.

Land use in the watershed is primarily agricultural. Approximately 60.2 percent of the landuse is cropland (cultivated and non-cultivated) and 39.8 percent is range and pastureland. Thirty eight animal feeding areas/operations are located in the Medicine Creek watershed.

The major soil association found in the Medicine Creek watershed is the Millboro association. The Millboro association consists of deep, well drained, nearly level to moderately sloping clayey soils formed in clayey material.

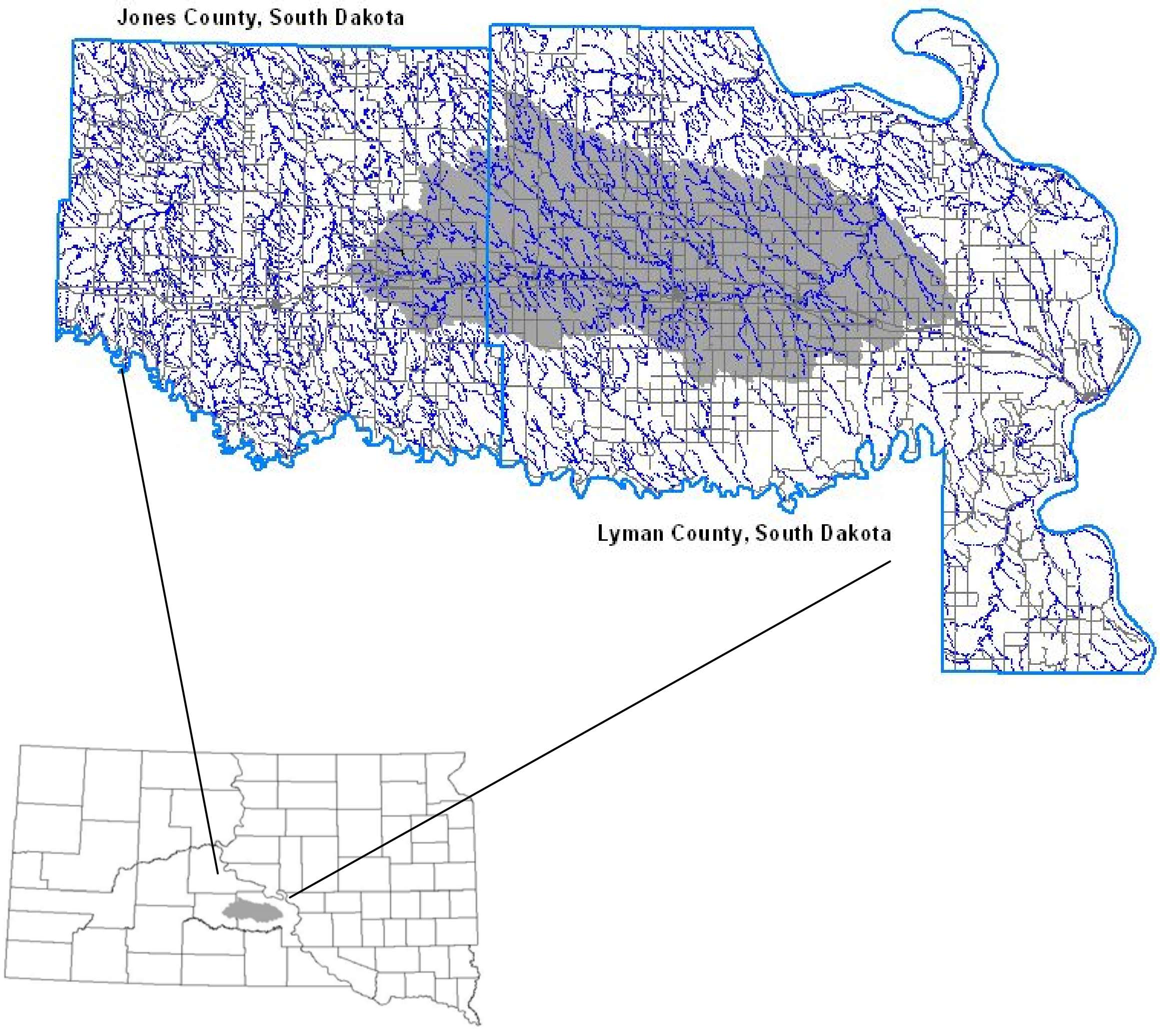


Figure 1. The Medicine Creek watershed and its location in the State of South Dakota.

The average annual precipitation in the watershed is 17 inches of which 13 inches or nearly 80% usually falls in April through September. During this study (April 2000 through May 2001) 22.1 inches of rainfall was recorded in Kennebec, South Dakota. Tornadoes and severe thunderstorms strike occasionally. These storms are local and of short duration and occasionally produce heavy rainfall events. The average seasonal snowfall is 30.9 inches per year (USDA, 1987).

Land elevation ranges from about 720 m (2,362 feet msl) in the western sections of the watershed to about 450 m (1,476 feet msl) at the southeastern boundary of the Lower Brule Reservation on Medicine Creek.

The entire Medicine Creek watershed is in the Northwestern Great Plains (43) ecoregion (Level III). Level III ecoregions can be refined to Level IV to elicit more resolution and landscape conditions. The entire Medicine Creek watershed is located in one Level IV ecoregion, the Subhumid Pierre Shale Plains (43f), located within the Northwestern Great Plains (43) (Bryce et al., 1998).

In the 1998 South Dakota Unified Watershed Assessment, the Medicine Creek Hydrologic Unit Code (HUC # 10140104) was scored, categorized and ranked as being a watershed in need of restoration. Some factors involved in the ranking were landuse, treatment needs and point source density; but the ranking was weighted based on the density of TMDL (Total Maximum Daily Load) acres within the HU. The final priority ranking for Medicine Creek was 4 out of a total 39 HU (watersheds) assessed in this manner (SD DENR, 1998b).

The 1999 South Dakota Nonpoint Source Management Plan schedule is based on the 1998 Section 305(b) report and the related 1998 Section 303(d) list of impaired waters needing TMDL.

Since 1999, South Dakota Department of Environment and Natural Resources (SD DENR) has monitored Medicine Creek as part of its Water Quality Monitoring (WQM) program. Assessment and WQM data will be used as an indication of use support for Medicine Creek.

2.0 Project Goals, Objectives and Activities

Goals

The long-term goal of the Medicine Creek Watershed Assessment Project is to locate and document sources of nonpoint source pollution in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to drive a watershed implementation project to improve sedimentation and nutrient problems with the creeks and lakes in the watershed. This project will result in four TMDL reports for four Integrated Report listed waters.

Project Description

Medicine Creek is a natural stream that drains portions of Lyman and Jones Counties in South Dakota and is the outlet tributary for Brakke Dam, Fate Dam and Byre Lake in Lyman County. The creek and the lakes receive runoff from agricultural operations and the lakes have experienced declining water quality based on Trophic State Index. The Medicine Creek watershed is approximately 390,072 acres with 11,288 acres above Brakke Dam, 17,202 acres above Fate Dam and 22,946 acres above Byre Lake. The watershed is predominately agricultural land use with cropland and grazing.

This project is intended to be the initial phase of a watershed-wide restoration project. Through water quality monitoring, stream gauging, stream channel analysis and land use analysis, the sources of impairment to the stream and the watershed will be documented and feasible alternatives for restoration will be presented in the final project report.

All of objective 1 and portions of objective 2 were completed and analyzed separately in Fate Dam, Brakke Dam and Byre Lake reports (Smith, 2004a; Smith 2004 and Smith 2003, respectively).

Objectives and Activities

OBJECTIVE 1: The objective of this task is to determine current conditions in the lakes and calculate the trophic state of each lake. This information will be used to determine the total amount of nutrient and sediment trapping that is occurring in each of the lakes and the amount of nutrient and sediment reduction required to improve the trophic condition of Fate Dam, Brakke Dam and Byre Lake.

Task 1 Nutrient and solids parameters will be sampled at two in-lake sites on Medicine Creek, Brakke Dam and Byre Lake. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre. Samples will be collected from the surface and bottom of Medicine Creek, Brakke Dam and Byre Lake on a monthly schedule, except during periods of unsafe ice cover, for a period of 1 year. The total number of samples to be collected will be 120 for all three lakes in the project area.

Task 2 The purpose of the in-lake samples is to assess ambient nutrient concentrations in the lake and identify trophic states. Water column dissolved oxygen and temperature profiles will be collected on a monthly basis. Water samples will be collected with a Van Dorn sampler and the sample bottles will be iced and shipped to the lab by the most rapid means available. Fecal coliform samples will be analyzed by the SD State Health Lab in Pierre. All other biological samples will be analyzed by staff from Watershed Protection in the Matthew Training Center Laboratory, Pierre, SD.

Task 3 All samples will be collected using the methods described in the "*Standard Operating Procedures for Field Samplers*" by the State of South Dakota Water Resources Assistance Program.

SITE	LOCATION	STORET NUMBER
Lake Sampling Locations – Fate Dam		
FD-1	Lat. 43.938726 Long. -100.007263 This site is located in the south central portion of the lake.	
FD-2	Lat. 43.944529 Long. -100.009913 Approximate north central portion of the lake	

Lake Sampling Locations – <u>Brakke Dam</u>

BD-1 Lat. 43.884496
Long. –99.944617
This site is located in the south central portion of the lake.

BD-2 Lat. 43.893604
Long. -99.954908
Approximate north central portion of the lake.

Lake Sampling Locations – <u>Byre Lake</u>

BL-1 Lat. 43.92978
Long. –99.83468
This site is located in the southeast portion of the lake.

BL-2 Lat. 43.92798
Long. -99.84155
Approximate northwest portion of the lake.

OBJECTIVE 2: Estimate the sediment and nutrient loadings from Medicine Creek and the individual tributaries in the Fate Dam, Brakke Dam and Byre Lake watersheds through hydrologic and chemical monitoring. The information will be used to locate critical areas in the watershed to be targeted for implementation.

<u>TASK 4</u> Install water level recorders on tributary monitoring sites and maintain a continuous stage record for the project period, with the exception of winter months after freeze up (Figure 2).

<u>Site</u>	<u>Location</u>
MCT-1	Lat. 43.955531 Long. -100.328842
MCT-2	Lat. 43.926020 Long. -100.186033
MCT-3	Lat. 43.944717 Long. -100.130243
MCT-4	Lat. 43.947701 Long. -100.089670
MCT-5	Lat. 44.009901 Long. -100.086023
MCT-6	Lat. 43.973990 Long. -100.048308

MCT-7	Lat.	43.923644
	Long.	–100.077286
MCT(FDO-8)	Lat.	43.938141
	Long.	-100.002275
MCT-9	Lat.	43.896513
	Long.	-100.023068
MCT(BDO-10)	Lat.	43.897975
	Long.	-99.953841
MCT-11	Lat.	43.861707
	Long.	-99.954456
MCT-12	Lat.	43.859372
	Long.	-99.923395
MCT-13	Lat.	43.911083
	Long.	-99.822682
MCT-14	Lat.	43.948913
	Long.	–99.885828
MCT-15	Lat.	43.926849
	Long.	–99.832414

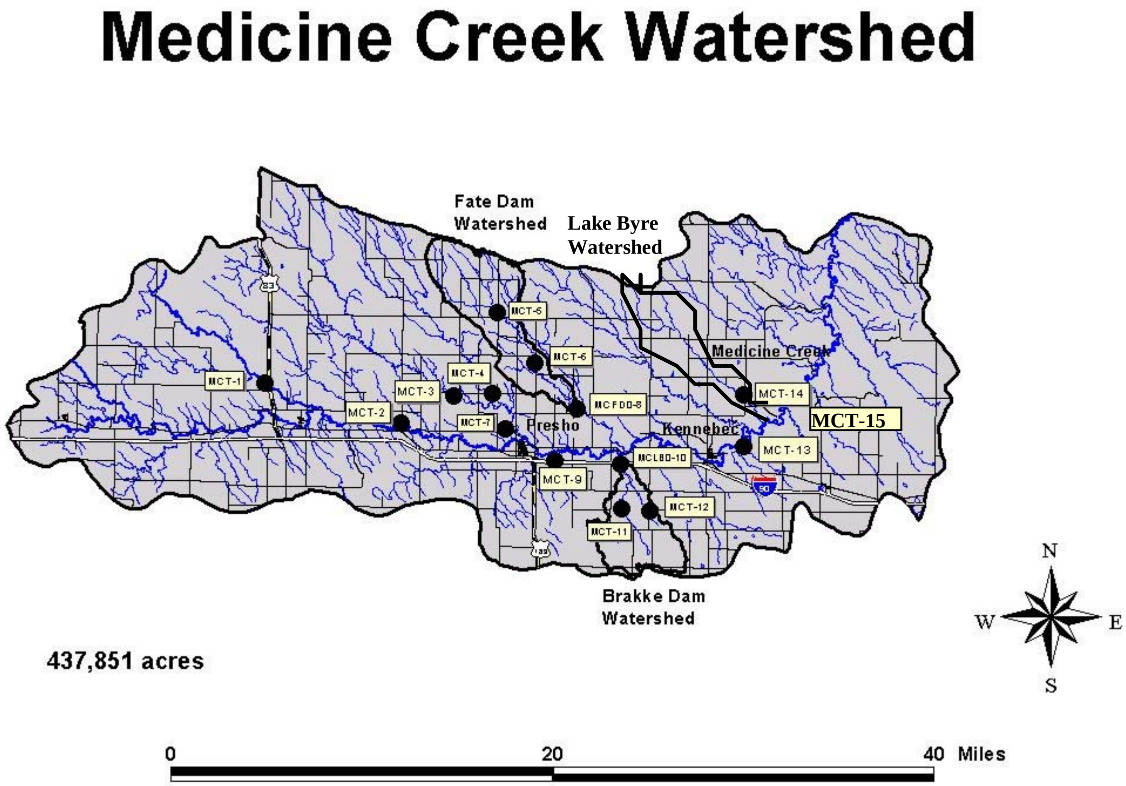


Figure 2. Medicine Creek watershed, Lyman and Jones Counties, South Dakota.

TASK 5 Discrete discharge measurements will be taken on a regular schedule and during storm surges. Discharge measurements will be taken with a hand-held current velocity meter.

TASK 6 Discharge measurements and water level data will be used to calculate a hydrologic budget for the creek system. This information will be used with concentrations of sediment and nutrients to calculate loadings from the watershed.

TASK 7 Collect water quality samples from 15 tributary monitoring sites. Samples will be collected during spring runoff, storm events, and monthly base flows. Proposed water quality monitoring sites may be found in Figure 2.

TASK 8 Samples will be collected twice weekly during the first week of spring snowmelt runoff and once a week thereafter until runoff ceases. Storm events and base flows will be sampled throughout the project period for an estimated total number of 148 samples.

PARAMETERS MEASURED FOR TRIBUTARY SAMPLES

PHYSICAL	CHEMICAL	BIOLOGICAL
Air temperature	Total solids	Fecal coliform bacteria
Water temperature	Total suspended solids	E. coli
Discharge	Dissolved oxygen	
Depth	Ammonia	
Visual observations	Un-ionized ammonia (calculated)	
Water level	Nitrate-nitrite	
	TKN	
	Total phosphorus	
	Total dis. phosphorus	
	Field pH	

QUALITY ASSURANCE/QUALITY CONTROL:

Approved QA/QC procedures will be utilized on all sampling and field data collection on the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Project Plan for the details of the procedures to be followed.

PRODUCTS:

A tributary water quality report, which will include a description of the relationship and influence of chemical and physical data. Hydrologic and nutrient loads will be calculated for the entire watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Water samples will be collected with a suspended sediment sampler when possible. All sample bottles will be iced and shipped to the lab and collected using the methods described in the "*Standard Operating Procedures for Field Samplers*" by the State of Dakota Water Resources Assistance Program. Nutrient and solids parameters will be sampled at fourteen tributary sites in the Medicine Creek watershed. All samples will be analyzed by the South Dakota State Health Laboratory in Pierre, SD. The watershed water quality data will be integrated with hydrologic loading to provide a complete analysis of the Medicine Creek, Brakke Dam, Fate Dam and Byre Lake hydrologic systems.

OBJECTIVE 3: Ensure that all water quality samples are accurate and defendable through the use of approved Quality Assurance/Quality Control procedures.

TASK 9 The collection of all field water quality data will be accomplished in accordance with the "*Standard Operating Procedures for Field Samplers*", South Dakota Water Resources Assistance Program.

TASK 10 A minimum of 10 percent of all the water samples collected will be QA/QC samples. QA/QC samples will consist of field blanks and field duplicate samples. An estimated 50 QA/QC samples will be collected during the project.

TASK 11 All QA/QC activities will be conducted in accordance with the Water Resources Assistance Program Quality Assurance Project Plan.

TASK 12 The activities involved with QA/QC procedures and the results of QA/QC monitoring will be compiled and reported in a section of the final project report and in all project reports.

PRODUCTS:

A Quality Assurance/Quality Control monitoring report.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Approved QA/QC procedures will be utilized on all sampling and field data collected during the Medicine Creek project. Please refer to the South Dakota Water Resources Assistance Program Quality Assurance Plan and the South Dakota Water Resources Assistance Program Standard Operating Procedures for Field Samplers for details of the procedures to be followed.

OBJECTIVE 4: Evaluation of agricultural impacts on the water quality of the watershed using the Annualized Agricultural Nonpoint Source (AnnAGNPS) model.

TASK 13 The Medicine Creek, Medicine Creek, and Brakke Dam watersheds will be modeled using the AnnAGNPS model. AnnAGNPS is a comprehensive land use model which estimates soil loss and delivery and evaluates the impact of livestock feeding areas. The watershed will be divided into cells. Each cell will be analyzed using 21 separate parameters with additional information collected for animal feeding operations.

TASK 14 The model will be used to identify critical areas of nonpoint source pollution to the surface waters in the watershed. Contributors of nutrients and sediment to surface water in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds will be identified.

PRODUCTS:

Report on land use in the watershed.
Recommendations for remediation of pollution sources in the watershed.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

OBJECTIVE 5: Public participation and involvement will be provided for and encouraged.

TASK 15 Informational meetings will be held on a quarterly basis for the general public and to inform the involved parties of progress on the study. These meetings will provide an avenue for input from the residents in the area.

TASK 16 News releases will be prepared and released to local news media on a quarterly basis. These releases will be provided to local newspapers, radio stations and TV stations.

PRODUCTS:

Public input to the project.
Information and education about the Medicine Creek project.
Involvement and input from the public will be documented.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

Informational meetings will be held on a frequent basis for the general public to inform the involved parties of progress on the study and provide a means of public input.

OBJECTIVE 6: Development of watershed restoration alternatives.

TASK 17 Once the field data is collected, an extensive review of the historical and project data will be conducted.

TASK 18 Loading calculations based on project data will be done and a hydrologic, sediment and nutrient budget will be developed for each watershed.

TASK 19 The results of the AnnAGNPS modeling of the watershed will be used in conjunction with the water quality and hydrologic budget to determine critical areas in the watersheds.

TASK 20 Feasible management practices will be compiled into a list of alternatives for the development of an implementation project and included in the final project report.

PRODUCTS:

A list of viable watershed restoration alternatives and recommendations for the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

RESPONSIBLE AGENCIES:

Task Prioritization:

Project Coordinator
Project Sponsor

Design and Technical Assistance:

South Dakota Department of Environment and Natural Resources

WORK ACTIVITIES:

An extensive review and study of the historical and current data will be done to determine the Best Management Practices and hydrologic restoration techniques needed to improve water quality and reduce sediment transport in the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds.

OBJECTIVE 7: Produce and publish a final report containing water quality results and restoration alternatives.

TASK 21: Produce loading calculations based on water quality sampling and hydrologic measurements.

TASK 22 Summarize the results of the AnnAGNPS model for the watershed and report locations of critical areas.

TASK 23 Write a summary of historical water quality and land use information and compare with project data to determine any possible trends.

TASK 24 Based on data, evaluate the hydrology of the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds and the chemical, biological, and physical condition of the streams.

TASK 25 Produce a summary report of all QA/QC activities conducted during the project and include in the final project report.

TASK 26 Write a description of feasible restoration alternatives for use in planning watershed nonpoint source implementation.

PRODUCTS:

A final report incorporating all previously described objectives

RESPONSIBLE AGENCIES:

South Dakota Department of Environment and Natural Resources

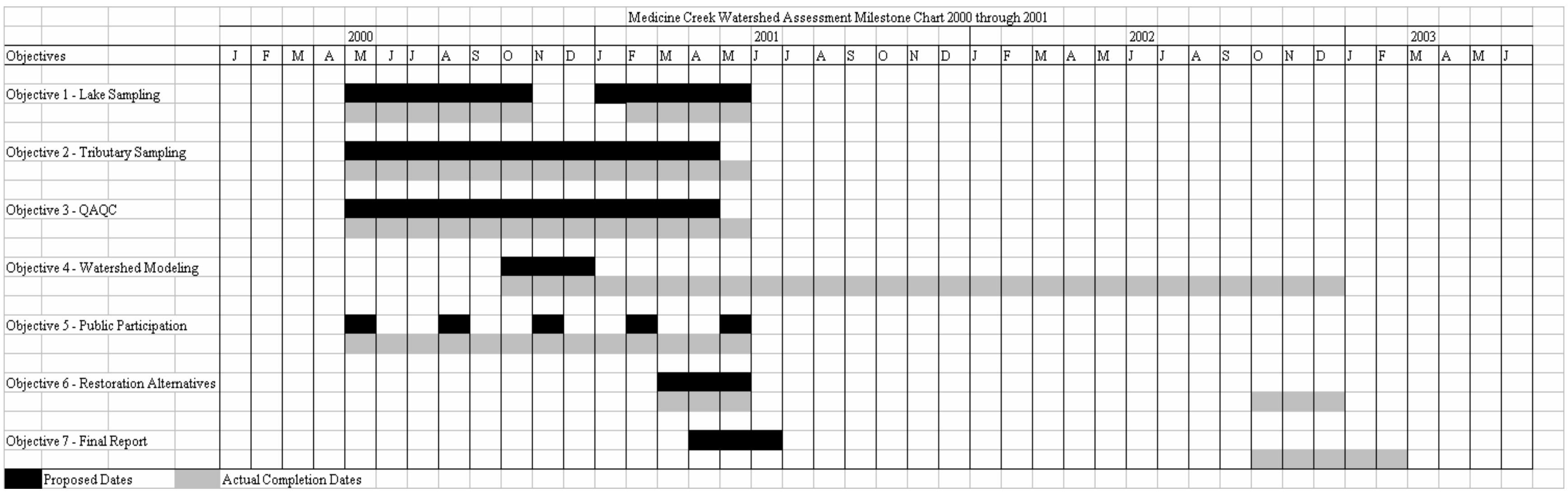
WORK ACTIVITIES:

Statistical evaluation of all water quality and field data produced during the course of the study. A review and compilation of historical data will be completed. Restoration alternatives will be developed. Graphic presentations of the information will be produced.

2.1 Planned and Actual Milestones, Products and Completion Dates

The Medicine Creek Assessment Project was started in April 2000. The sampling effort continued through May 2001. Difficulty was encountered in the collection of Annualized Agricultural Nonpoint Source Model (AnnAGNPS) landuse data which was not completed until fall 2003. This situation resulted in a delay in watershed modeling and report generation. See the attached Medicine Creek Assessment Project milestone table (Table 1).

Table 1. Proposed and actual completion dates for the Medicine Creek Watershed Assessment Project, 2000 through 2001.



2.2 Evaluation of Goal Achievement

Medicine Creek, Fate Dam, Brakke Dam and Byre Lake are listed in the State of South Dakota's 2004 Integrated Report (combined 305(B) and 303(d) reports) as a category 5 (water impaired/requires a TMDL) for Trophic State Index (TSI) for increased nutrients from nonpoint source pollution. Medicine Creek is also listed on the states 303(d) list for conductivity and total dissolved solids. This study assessed Medicine Creek, Fate Dam, Brakke Dam, Byre Lake and their watersheds for background data to develop TMDLs, identified targeted areas of increased nutrient and sediment load impacting specific watersheds and recommend specific Best Management Practices (BMPs) for targeted areas in these watersheds. The project meets one of the goals of the Non Point Source (NPS) program by assessing impaired waterbodies on the 303(d) list and has met all project goals outlined above. A future implementation project is planned in the near future.

2.3 Supplemental Information

Loading reduction estimates for suggested BMPs outlined in this report were derived from AnnAGNPS Modeled landuse data. The AnnAGNPS Model estimated the expected load reduction after application of selected BMPs within the Medicine Creek, Fate Dam, Brakke Dam and Byre Lake watersheds. These practices should be implemented on targeted areas having increased nutrient and sediment export coefficients (loading). Implementing recommended BMPs within the watershed will have the greatest effect on reducing overall loading to Medicine Creek, Fate Dam, Brakke Dam and Byre Lake.

3.0 Monitoring Results

Tributary Methods

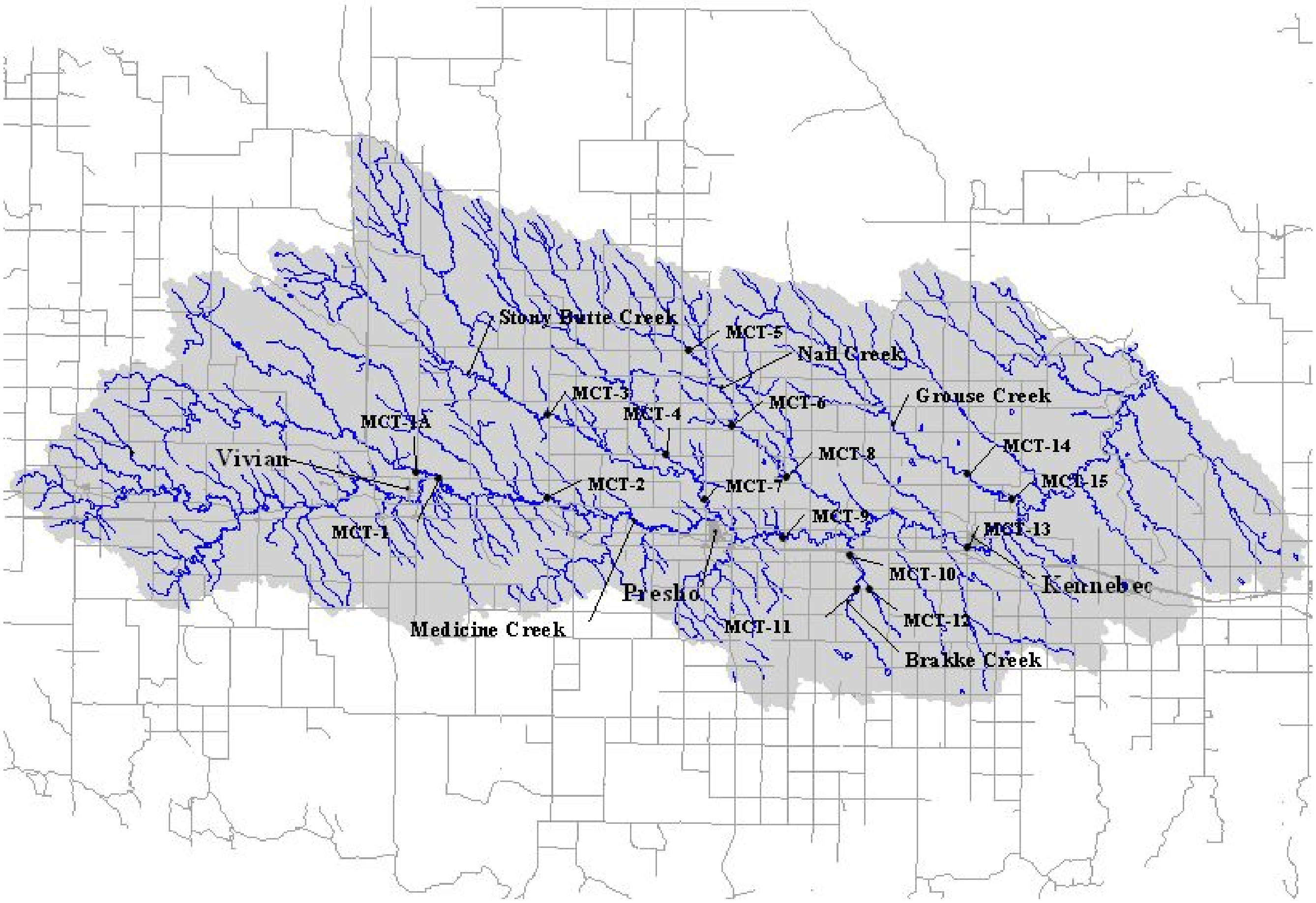


Figure 3. Medicine Creek sampling sites from 2000 through 2001.

Sixteen tributary locations were chosen for collecting hydrologic, nutrient and sediment information from the Medicine Creek watershed (Figure 3). Tributary site locations were chosen that would best show watershed managers which sub-watersheds were contributing the largest nutrient and sediment loads to Medicine Creek and ultimately Lake Sharpe. OTT Thalimedes data loggers were placed throughout the watershed. Monitoring sites were placed in the North Fork of Medicine Creek (MCT-1A), Stony Butte Creek (MCT-3 and MCT-7), on an unnamed tributary to Stony Butte Creek (MCT-4), upper Nail Creek ((MCT-5), Nail Creek near the inlet to Fate Dam (MCT-6) and near the outlet spillway of Fate Dam (MCT-8)). OTT Thalimedes were also placed in Brakke Creek on the east and west tributaries of Brakke Creek near the inlets to Brakke Dam (MCT-11 and MCT-12) and near the outlet spillway of Brakke Dam (MCT-10), Grouse Creek inlet to Byre Lake (MCT-14) and near the outlet spillway of Byre Lake (MCT-15).

Four mainstem monitoring sites (MCT-1, MCT-2, MCT-9 and MCT-13) were setup on Medicine Creek.

The data loggers were checked and downloaded bi-monthly to update the database and check for mechanical problems. All discharge data was collected according to South Dakota's *Standard Operating Procedures for Field Samples, Volume I* (SD DENR, 2005).

Stage discharge regression graphs and equations for each tributary monitoring site are provided in Appendix A (Figure A-1 through Figure A-10).

During the project, MCT-5 on Nail Creek was a bridge site; however, immediately after the project was over the county removed the bridge and replaced it with a two seven-foot wide corrugated culverts. Discharge measurements were not collected at this site due to poor access during bad weather. Thus, average daily stage data at MCT-5 was used as stage inside the corrugated metal conduit to calculate average daily discharge using the Manning's formula (Equation 1). Manning's formula was also used to calculate average discharge at MCT-6 (Fate Dam inlet) and MCT-11 (west tributary, Brakke Creek).

Equation 1. Manning formula for discharge.

$$Q = \frac{K * A * R^{2/3} * S^{1/2}}{n}$$

Where: Q = Flow rate in cfs
K = 1.49 (cfs)
A = Cross sectional area of flow
R = Hydraulic radius (cross sectional area divided by the wetted parimeter)
S = Slope of the hydraulic gradient
n = Manning's coefficient of roughness dependent upon material of conduit

Average daily outlet (MCT-8, MCT-10 and MCT-15) stage data for Fate Dam, Brakke Dam and Byre Lake spillways were used to calculate discharge using a standard weir equation (Equation 2).

Equation 2. Medicine Creek weir discharge equation.

$$Q = C * L * \left(H^{3/2}\right)$$

Where: Q = Flow rate in cfs
L = Length (width of spillway)
H = Stage Height
C = Coefficient, C = 2.3

Hydrologic Data Collection Methods

Instantaneous discharge measurements were collected for each station during the time each sample was collected. A Marsh-McBirney Model 201 flow meter was used to collect discharge measurements.

Tributary Water Quality Sampling

Samples collected at each tributary site were taken according to South Dakota's *Standard Operating Procedures for Field Samplers* (SD DENR, 2005). Tributary physical, chemical and biological water quality sample parameters are listed in Table 2. All water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for approximately 10 percent of the samples according to South Dakota's EPA approved *Non-Point Source Quality Assurance/Quality Control Plan* (SD DENR, 1998c). These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254 or at http://www.state.sd.us/denr.

Table 2. Tributary physical, chemical and biological parameters analyzed in , Lyman County, South Dakota in 2000 through 2001.

Physical	Chemical	Biological
Air Temperature	Total Alkalinity	Fecal Coliform
Water Temperature	Field pH	E. coli
Depth	Dissolved Oxygen	
Visual Observations	Total Solids	
	Total Suspended Solids	
	Total Dissolved Solids (calculated)	
	Volatile Total Suspended Solids	
	Ammonia	
	Un-ionized Ammonia (calculated)	
	Nitrate-Nitrite	
	Total Kjeldahl Nitrogen	
	Total Phosphorus	
	Total Dissolved Phosphorus	
	Conductivity	

Tributary Modeling Methods

Tributary Loading Calculations

The FLUX program was used to develop nutrient and sediment loadings for all tributary monitoring sites in Medicine Creek. The US Army Corp of Engineers developed the FLUX program for eutrophication (nutrient enrichment) assessment and prediction for reservoirs (Walker, 1999). The FLUX program uses six different calculation techniques (methods) for calculating nutrient and sediment loadings. The sample and flow data for this program can be stratified (adjusted) until the coefficient of variation (standard error of the mean loading divided by the mean loading =CV) for all six methods converge or are all similar. The uncertainty in the estimated loading is reflected by the CV value. The lower the CV value the greater the accuracy (less error) there is in loading estimates. This scenario was applied to each relevant sampling parameter to determine the appropriate method (model) for specific parameters. Methods (models) and CV values for each parameter and sampling site are listed in Table 3. These methods were used on the tributary site (inlet site) and the outlet site of Medicine Creek to calculate nutrient and sediment loadings and retention for this project.

After the loadings for all sites were completed, export coefficients were developed for each of the parameters. Export coefficients are calculated by taking the total nutrient or sediment load (kilograms) and dividing by the total area of the sub-watershed (in acres). This calculation results in the determination of the number of kilograms of sediment and nutrients per acre delivered from that sub-watershed (kg/acre). These values were used to target areas within the watershed with excessive nutrient and sediment loads. These areas will also be used to target recommended BMPs for a projected implementation project.

Table 3. Model and coefficient of variation by parameter for FLUX loading analysis in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

	MCT-1		MCT-1A		MCT-2		MCT-3		MCT-4		MCT-5		MCT-6		MCT-7	
	(Medicine Creek)		(North Fork of Medicine Creek)		(Medicine Creek)		(Stony Butte Creek)		(Stony Butte Creek)		(Upper Nail Creek)		(Fate Dam Inlet)		(Stony Butte Creek)	
Parameter	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)
Alkalinity	Q wt C	0.060	Q wt C	0.075	Q wt C	0.139	Q wt C	0.012	Q wt C	0.206	Q wt C	0.060	IJC	0.003	Q wt C	0.593
Total Solids	Q wt C	0.218	Q wt C	0.095	Q wt C	0.177	Q wt C	0.480	Q wt C	0.412	Q wt C	0.094	Q wt C	0.536	Q wt C	1.289
Total Dissolved Solids	Q wt C	0.040	Q wt C	0.295	Q wt C	0.258	IJC	0.009	Q wt C	0.201	Q wt C	0.111	Q wt C	0.081	Q wt C	1.305
Total Suspended Solids	IJC	0.661	IJC	0.804	Q wt C	0.463	IJC	0.791	Q wt C	0.744	IJC	0.017	Q wt C	1.081	Q wt C	1.286
Volatile Total Suspended Solids	Q wt C	0.612	IJC	0.774	Q wt C	1.932	IJC	0.667	Q wt C	0.822	Q wt C	0.198	Q wt C	0.819	Q wt C	0.846
Ammonia	Q wt C	0.698	Q wt C	0.609	Q wt C	0.954	IJC	0.450	Q wt C	0.613	IJC	0.122	Q wt C	1.257	IJC	0.329
Nitrate-Nitrite	Q wt C	0.279	Q wt C	0.489	Q wt C	0.720	Q wt C	0.186	Q wt C	0.087	Q wt C	0.201	Q wt C	0.233	Av. Load	0.502
Total Kjeldahl Nitrogen	Q wt C	0.141	Q wt C	0.068	Q wt C	0.344	Q wt C	0.172	IJC	0.054	Q wt C	0.260	Q wt C	0.193	Q wt C	0.475
Inorganic Nitrogen	Q wt C	0.283	Q wt C	0.489	Q wt C	0.722	Q wt C	0.115	Q wt C	0.124	Q wt C	0.195	Q wt C	0.264	Av. Load	0.469
Organic Nitrogen	Q wt C	0.111	IJC	0.023	Q wt C	0.315	Q wt C	0.146	IJC	0.072	Q wt C	0.291	Q wt C	0.030	Q wt C	0.595
Total Nitrogen	Q wt C	0.257	Q wt C	0.448	Q wt C	0.666	IJC	0.023	IJC	0.050	Q wt C	0.210	Q wt C	0.103	Av. Load	0.382
Total Phosphorus	IJC	0.527	Q wt C	0.270	Q wt C	0.347	IJC	0.625	Q wt C	0.234	Q wt C	0.128	Q wt C	0.610	Q wt C	0.325
Total Dissolved Phosphorus	Q wt C	0.427	Q wt C	0.287	IJC	0.043	Q wt C	0.101	Q wt C	0.221	Q wt C	0.133	Q wt C	0.014	IJC	0.299
Total Flow (HM^3)		**5.824**		**4.559**		**13.235**		**1.495**		**1.283**		**1.717**		**3.790**		**3.070**

Table 3 (continued) Model and coefficient of variation by parameter for FLUX loading analysis in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

	MCT-8		MCT-9		MCT-10		MCT-11		MCT-12		MCT-13		MCT-14		MCT-15	
	(Fate Dam Outlet)		(Medicine Creek)		(Brakke Dam Outlet)		(Brakke Creek) (Brakke Creek Inlet)		(Brakke Creek) (Brakke Creek Inlet)		(Medicine Creek)		(Grouse Creek) (Byre Lake Inlet)		(Byre Lake Outlet)	
Parameter	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)	Model (Method)	Coefficient of Variation (CV)
Alkalinity	Q wt C	0.174	Q wt C	0.161	IJC	0.015	IJC	0.126	Q wt C	0.214	Q wt C	0.108	IJC	0.003	Q wt C	0.131
Total Solids	Q wt C	0.034	IJC	0.259	Q wt C	0.016	Q wt C	0.261	Q wt C	0.160	Q wt C	0.039	IJC	0.421	Q wt C	0.034
Total Dissolved Solids	IJC	0.024	IJC	0.500	IJC	0.044	Q wt C	0.187	Q wt C	0.124	IJC	0.073	IJC	0.117	Q wt C	0.113
Total Suspended Solids	Q wt C	0.530	Q wt C	0.085	Q wt C	0.193	Q wt C	0.473	Q wt C	0.286	IJC	0.052	IJC	0.736	Q wt C	0.479
Volatile Total Suspended Solids	Q wt C	0.556	Q wt C	0.130	IJC	0.231	IJC	0.126	Q wt C	0.561	Q wt C	0.327	IJC	0.743	IJC	0.050
Ammonia	Q wt C	1.501	Q wt C	1.422	IJC	0.196	IJC	0.679	IJC	0.335	Q wt C	0.387	IJC	0.148	Q wt C	0.617
Nitrate-Nitrite	Q wt C	0.481	Q wt C	1.311	Q wt C	0.143	Q wt C	0.153	IJC	0.431	Q wt C	0.948	Q wt C	0.173	Q wt C	0.229
Total Kjeldahl Nitrogen	IJC	0.008	Q wt C	0.875	Q wt C	0.080	IJC	0.300	Q wt C	0.204	Q wt C	0.432	Q wt C	0.181	Q wt C	0.346
Inorganic Nitrogen	Q wt C	0.461	Q wt C	1.327	IJC	0.149	IJC	0.184	IJC	0.364	Q wt C	0.706	Q wt C	0.173	Q wt C	0.212
Organic Nitrogen	IJC	0.030	Q wt C	0.740	IJC	0.095	IJC	0.276	Q wt C	0.207	Q wt C	0.441	Q wt C	0.218	IJC	0.073
Total Nitrogen	Q wt C	0.317	Q wt C	1.193	Q wt C	0.017	IJC	0.226	IJC	0.157	IJC	0.248	Q wt C	0.008	Q wt C	0.438
Total Phosphorus	Q wt C	0.457	IJC	0.051	Q wt C	0.378	Q wt C	0.182	Q wt C	0.658	IJC	0.469	IJC	0.562	Q wt C	0.360
Total Dissolved Phosphorus	Q wt C	0.451	IJC	0.120	Q wt C	0.495	IJC	0.068	Q wt C	0.678	Q wt C	0.661	IJC	0.094	Q wt C	0.283
Total Flow (HM^3)		**3.379**		**16.361**		**0.901**		**1.461**		**0.137**		**24.321**		**7.313**		**5.843**

Q wt C = Flow weighted Concentration model

IJC = International Joint Committee model (modifies Q wt C by a factor to adjust for bias where concentrations varies with flow)

Avg. Load = Average Load (modeled independently of flow)

Tributary Statistical Analysis

Tributary data was analyzed using StatSoft® statistical software (STATISTICA version 7.0). Kruskal-Wallis ANOVA (multiple comparison non-parametric analysis) was run on tributary concentration and loading data to determine significant differences between tributary monitoring sites. Statistical results for both concentration and loading data for all parameters are provided in Table 4.

Only tributary parameters that were significantly different between sampling sites are discussed by parameter when applicable. Significant differences by parameter and sub-watersheds using multiple comparison matrix tables are provided in Appendix B, Tables B-1 through Table B-32.

Table 4. Kruskal-Wallis (H) values, observations and p values for tributary concentration and loading data for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

	Concentration			Loading	
Parameter	N	Kruskal-Wallis (H)	p-value	Kruskal-Wallis (H)	p-value
Dissolved Oxygen	114	28.6	0.018	-	-
pH	114	31.8	0.006	-	-
Conductivity @ 25° C	95	67.7	0.000	-	-
Water Temperature	117	16.2	0.369	-	-
Fecal Coliform Bacteria (all dates)	116	21.9	0.108	-	-
Fecal Coliform Bacteria (mainstem-May-Sept.)	32	2.73	0.604		
E. coli Bacteria (mainstem May-Sept.)	12	8.21	0.084	-	-
Alkalinity	117	52.3	0.000	17.4	0.296
Total Solids	117	85.7	0.000	25.3	0.046
Total Dissolved Solids	118	78.4	0.000	24.1	0.063
Total Suspended Solids	116	19.4	0.195	25.9	0.039
Volatile Total Suspended Solids	117	25.4	0.044	24.3	0.061
Ammonia	118	11.4	0.721	22.4	0.097
Un-ionized Ammonia	118	31.8	0.007	-	-
Nitrate-Nitrite	118	77.7	0.000	26.1	0.037
Total Kjeldahl Nitrogen	118	63.1	0.000	18.8	0.223
Organic Nitrogen	118	64.5	0.000	19.7	0.185
Inorganic Nitrogen	118	77.9	0.000	25.5	0.043
Total Nitrogen	118	83.1	0.000	23.7	0.071
Total Phosphorus	118	37.7	0.001	24.3	0.061
Total Dissolved Phosphorus	118	55.5	0.000	19.8	0.180
Total Nitrogen to Total Phosphorus	118	80.5	0.000	-	-

Shaded = significantly different between sampling sites ($p<0.05$).

Landuse Modeling – Annualized Agricultural Non-Point Source Model, version 3.32a.34 (AnnAGNPS) and Agricultural Non-Point Source Model, version 3.65 (AGNPS)

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. AnnAGNPS (Annualized Agricultural Non-Point Source) is a landuse model to simulate/model sediment and nutrient loadings from watersheds. AnnAGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and reductions are calculated at the outlet to the watershed.

The input data set for AnnAGNPS Pollutant Loading Model consists of 33 sections of data, which can be supplied by the user in a number of ways. This model execution utilized; digital elevation maps (DEMs) to determine cell and reach geometry, SSURGO soil layers to determine primary soil types and the associated NASIS data tables for each soils properties, and primary land use based on a 40 acre grid pattern, collected initially with the intention of executing the AGNPS version 3.65 model. Impoundment data was obtained using Digital Ortho Quads (DOQs) layers using ArcView Global Information System (GIS)® software.

Climate/weather data from Pierre, South Dakota was used to generate simulated weather data. Model results are based on one years of climate data for initializing variables prior to 25-year watershed simulation. Simulated precipitation based on climate data ranged from 13 to 29 inches per year. Mean annual precipitation for this watershed is approximately 17 inches.

Part of the modeling process includes the assessment of Animal Feeding Operations (AFOs) located in the watershed. This assessment was completed with the assistance of American Creek Conservation District which provided estimates on the number of animal units and duration of use. AFO nutrient value loading and rating numbers were calculated using a SD DENR derived feedlot program. Derived nutrient values for each AFO were used to calculate feedlot/feeding area nutrient and rating values for use in the AnnAGNPS program.

Findings from the AnnAGNPS report can be found throughout the water quality and landuse modeling discussions of this document. Conclusions and recommendations will rely on both water quality and AnnAGNPS data. The complete AnnAGNPS report can be found in Appendix C.

3.1 Tributary Surface Water Chemistry

Tributary Water Quality Standards

South Dakota's numeric water quality standards are based on beneficial use categories. Beneficial use classifications are listed in Table 5. All streams in the state are assigned the beneficial uses (category 9) fish and wildlife propagation, recreation and stock watering and (category 10) irrigation (ARSD § 74:51:03:01).

Table 5. South Dakota's beneficial use classifications.

Category	Beneficial Use
1	Domestic water supply waters;
2	Coldwater permanent fish life propagation waters;
3	Coldwater marginal fish life propagation waters;
4	Warmwater permanent fish life propagation waters;
5	Warmwater semi-permanent fish life propagation waters;
6	Warmwater marginal fish life propagation waters;
7	Immersion recreation waters;
8	Limited-contact recreation waters;
9	Fish and wildlife propagation, recreation, and stock watering waters;
10	Irrigation waters; and
11	Commerce and industry waters.

Medicine Creek in Lyman County (from Highway 83 Bridge to Lake Sharpe) has been assigned the beneficial uses of (6) Warmwater marginal fish life propagation waters, (8) Limited-contact recreation waters, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water (Table 6).

In addition to physical and chemical standards, South Dakota has developed narrative criteria for the protection of aquatic life uses. *All waters of the state must be free from substances, whether attributable to human-induced point source discharge or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities* (ASRD § 74:51:01:12).

Table 6. Assigned beneficial uses for Medicine Creek, Lyman County South Dakota.

Water Body	From	To	Beneficial Uses*	County
Medicine Creek	Highway 83	Lake Sharpe	6, 8	Lyman
All Streams	Entire State	Entire State	9, 10	All

*** = See Table 5 above**

Each beneficial use classification has a set of numeric standards uniquely associated with that specific category. Water quality values that exceed those standards, applicable to specific beneficial uses, impair beneficial use and violate water quality standards. Table 7 lists the most stringent water quality parameters for Medicine Creek. Four of the nine parameters (total petroleum hydrocarbon, oil and grease, un-disassociated hydrogen sulfide and sodium adsorption ratio) listed for Medicine Creek beneficial use classification were not sampled during this project.

Table 7. The most stringent water quality standards for Nail Creek (Medicine Creek tributary) based on beneficial use classifications.

Water Body	Beneficial Uses	Parameter	Standard Value
Medicine Creek	6, 8, 9, 10	Un-ionized ammonia nitrogen as N [1]	$\leq$ 0.05 mg/L
		Dissolved oxygen	$\geq$ 5.0 mg/L
		pH	$\geq$ 6.0 - $\leq$ 9.0
		Total Suspended Solids [2]	$\leq$ 263 mg/L
		Temperature (°C)	$\leq$ 32.2°C
		Fecal coliform [3]	$\leq$ 2,000 colonies/100mL
		Total alkalinity as calcium carbonate [4]	$\leq$ 1313 mg/L
		Total dissolved solids [5]	$\leq$ 4,375 mg/L
		Conductivity at 25° C [6]	$\leq$ 4,375 µS/cm
		Nitrates as N [7]	$\leq$ 88 mg/L
		Undisassociated hydrogen sulfide [8]	$\leq$ 0.002 mg/L
		Total petroleum hydrocarbon [8]	$\leq$ 1 mg/L
		Sodium Adsorption Ratio (SAR) [8,9]	$\leq$ 10 (unit less)
		Oil and grease [8]	$\leq$ 10 mg/L

[1] = Un-ionized ammonia is the fraction of ammonia that is toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic. The 30-day standard is $\leq$ 0.05 mg/L and the daily maximum is 1.75 times the applicable criterion in the South Dakota Surface Water Quality Standards in mg/L based upon the water temperature and pH where the sample was taken.

[2] = The daily maximum for total suspended solids is $\leq$ 263 mg/L or $\leq$ 150 mg/L for a 30-day average (an average of 3 samples (minimum) taken in separate 24-hour periods).

[3] = The fecal coliform standard is in effect from May 1 to September 30. The $\leq$ 2,000 colonies/100 ml is for a single sample or $\leq$ 1,000 colonies/100 ml over a 30-day average (an average of 5 samples (minimum) taken in separate 24-hour periods).

[4] = The daily maximum for total alkalinity as calcium carbonate is $\leq$ 1,313 mg/L or $\leq$ 750 mg/L for a 30-day average.

[5] = The daily maximum for total dissolved solids is $\leq$ 4,375 mg/L or $\leq$ 2,500 mg/L for a 30-day average.

[6] = The daily maximum for conductivity at 25° C is $\leq$ 4,375 µS/cm or $\leq$ 2,500 µS/cm for a 30-day average.

[7] = The daily maximum for nitrates is $\leq$ 88 mg/L or 50 mg/L for a 30-day average.

[8] = Parameters not measured during this project.

[9] = The sodium absorption ratio is a calculated value that evaluates the sodium hazard of irrigation water based on the Gapon equation and expressed by the mathematical equation:

Equation 3. Sodium Adsorption Ratio (SAR), (Gapon Equation)

$$\text{SAR} = Na^{+} \Big/ \sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}$$

Where Na^{+}, Ca^{+2} and Mg^{+2} are expressed in milliequivalents per liter.

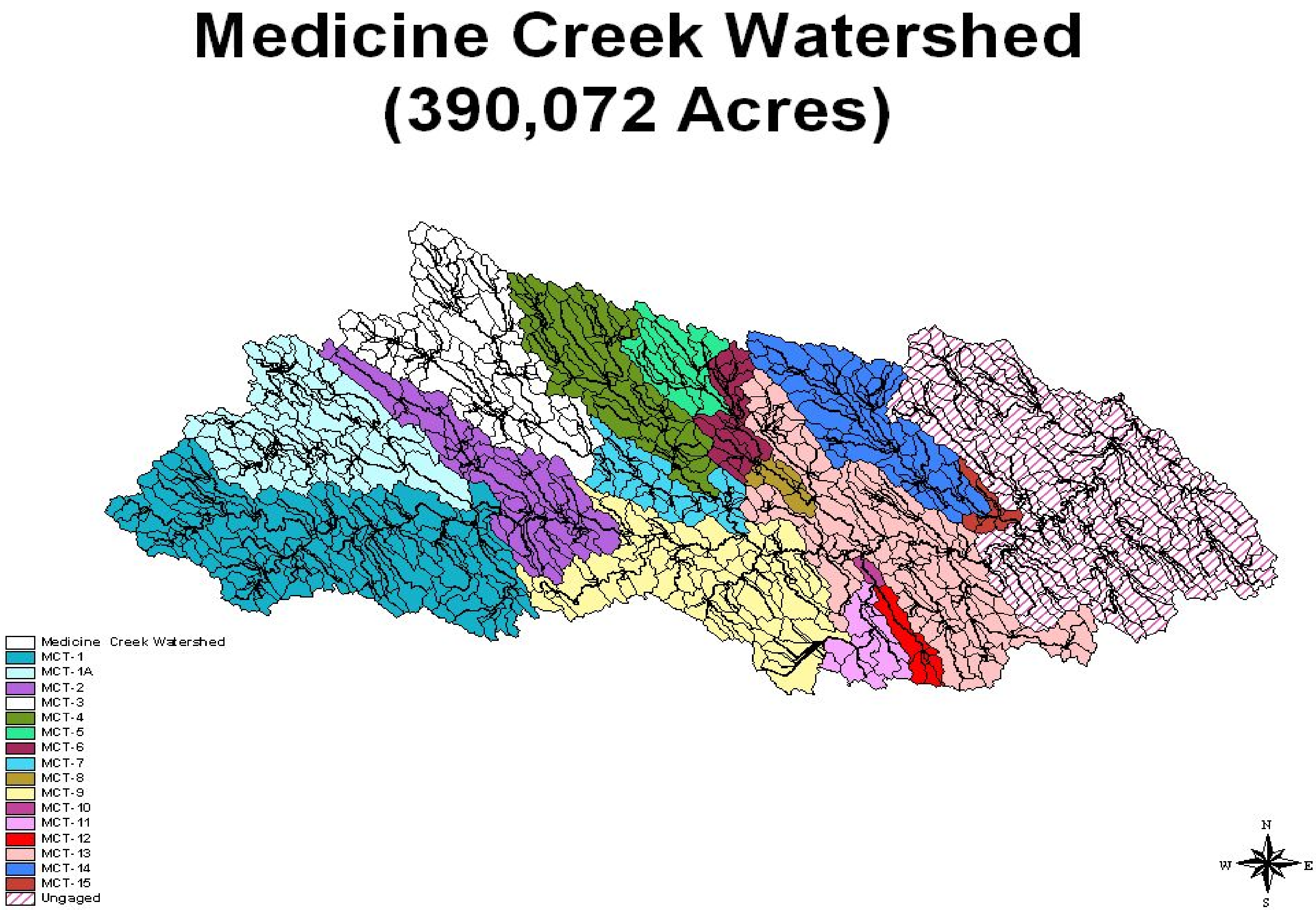


Figure 4. Medicine Creek sub-watersheds by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota 2000 through 2001

Medicine Creek Water Quality Exceedances

Thirty-two water quality standards violations in five parameters were observed in assessment data; while, 31 water quality standards violations in six parameters were observed in Water Quality Monitoring (WQM) data based on assigned beneficial uses for Medicine Creek (Table 8 through Table 13). Assigned beneficial uses for Medicine Creek are as follows: (6) Warmwater marginal fish life propagation waters, (8) Limited-contact recreation waters, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water. Sub-watershed locations are depicted in Figure 4.

Table 8. Long-term Specific Conductance (Conductivity @ 25° C) Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	Flow (CFS)	Conductivity @ 25° C (µS/cm)	Sample Total	Violation Total	Percent Violation
MCT-1	07/18/2000	0.35	4,640			
MCT-13	07/18/2000	0.11	4,630			
				47	2	4.3%
Site (WQM Data)						
WQM-141 (MCT-13)	08/19/1999	-	4,800			
WQM-141 (MCT-13)	02/22/2000	-	5,240			
WQM-141 (MCT-13)	04/17/2000	-	4,570			
WQM-141 (MCT-13)	07/19/2000	-	4,440			
WQM-141 (MCT-13)	08/21/2000	-	5,890			
WQM-141 (MCT-13)	09/18/2000	-	6,530			
WQM-141 (MCT-13)	10/10/2000	-	7,420			
WQM-141 (MCT-13)	11/20/2000	-	7,500			
WQM-141 (MCT-13)	12/18/2000	-	15,800			
WQM-141 (MCT-13)	01/08/2001	-	9,330			
WQM-141 (MCT-13)	02/12/2001	-	9,060			
WQM-141 (MCT-13)	10/22/2001	-	4,980			
WQM-141 (MCT-13)	11/19/2001	-	6,180			
WQM-141 (MCT-13)	01/07/2002	-	5,410			
WQM-141 (MCT-13)	02/05/2002	-	5,200			
WQM-141 (MCT-13)	03/18/2002	-	4,560			
WQM-141 (MCT-13)	06/17/2002	-	4,730			
WQM-141 (MCT-13)	01/07/2003	-	9,590			
WQM-141 (MCT-13)	02/24/2004	-	5,280			
WQM-141 (MCT-13)	05/18/2004	-	4,380			
				59	20	33.9%
Total				**106**	**22**	**20.7%**

- = No data

Table 9. Long-term Total Dissolved Solids Concentrations Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	Flow (CFS)	Total Dissolved Solids (mg/L)	Sample Total	Violation Total	Percent Violation
MCT-2	05/22/2001	0.09	5,931			
MCT-1A	05/31/2000	0.72	4,970			
MCT-9	04/20/2000	-	4,880			
MCT-13	04/12/2000	-	4,757			
MCT-1	05/30/2000	0.54	4,598			
MCT-1A	07/18/2000	0.04	4,506			
MCT-1	07/18/2000	0.35	4,437			
				64	7	10.9%
Site (WQM Data)						
WQM-141 (MCT-13)	01/07/2003	-	10,555			
WQM-141 (MCT-13)	01/08/2001	-	9,736			
WQM-141 (MCT-13)	12/18/2000	-	8,527			
WQM-141 (MCT-13)	02/12/2001	-	8,268			
WQM-141 (MCT-13)	11/20/2000	-	8,199			
WQM-141 (MCT-13)	10/10/2000	-	7,784			
WQM-141 (MCT-13)	09/18/2000	-	7,215			
WQM-141 (MCT-13)	08/21/2000	-	6,064			
WQM-141 (MCT-13)	11/19/2001	-	5,965			
WQM-141 (MCT-13)	02/22/2000	-	5,525			
WQM-141 (MCT-13)	01/07/2002	-	5,293			
WQM-141 (MCT-13)	02/24/2004	-	5,155			
WQM-141 (MCT-13)	10/22/2001	-	4,927			
WQM-141 (MCT-13)	04/17/2000	-	4,821			
WQM-141 (MCT-13)	02/05/2002	-	4,721			
WQM-141 (MCT-13)	08/19/1999	-	4,712			
				60	16	26.7%
Total				**124**	**23**	**18.5%**

- = No data

Table 10. Long-term Total Suspended Solids Concentrations Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	Flow (CFS)	Total Suspended Solids (mg/L)	Sample Total	Violation Total	Percent Violation
MCT-9	04/25/2001	261.59	1,760			
MCT-13	03/19/2001	302.32	1,220			
MCT-13	04/25/2001	1409.55	1,060			
MCT-1A	04/25/2001	139.55	840			
MCT-1	04/25/2001	225.35	740			
MCT-9	03/19/2001	574.33	630			
MCT-9	06/01/2000	2.58	338			
				62	7	**11.3%**
Site (WQM Data)						
WQM-141 (MCT-13)	03/19/2001	-	1,140			
WQM-141 (MCT-13)	04/01/2002	-	2,340			
WQM-141 (MCT-13)	07/15/2003	-	320			
				58	3	5.2%
Total				**120**	**12**	**10.0%**

- = No data

Table 11. Long-term Dissolved Oxygen Concentrations Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	Flow (CFS)	Dissolved Oxygen (mg/L)	Sample Total	Violation Total	Percent Violation
MCT-13	07/18/2000	0.36	4.70			
				62	1	1.6%
Site (WQM Data)						
WQM-141 (MCT-13)	01/08/2001	-	1.50			
				55	1	1.8%
Total				**117**	**2**	**1.7%**

- = No data

Table 12. Long-term Fecal Coliform Bacteria (colonies/100 ml) Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	Flow (CFS)	Fecal Coliform Bacteria (colonies/100 ml)	Sample Total	Violation Total	Percent Violation
MCT-1A	07/18/2000	0.04	34,000			
MCT-1	07/18/2000	0.10	5,600			
MCT-13	07/10/2000	0.36	4,800			
MCT-9	06/14/2000	1.26	2,200			
MCT-2	06/29/2000	0.09	2,200			
				32	5	**15.6%**
Site (WQM Data)						
WQM-141 (MCT-13)	06/18/2001	-	2,200			
WQM-141 (MCT-13)	07/15/2003	-	2,500			
				26	2	7.7%
Total				**58**	**7**	**12.1%**

- = No data

Table 13. Long-term pH Value Violations (Assessment and WQM) for Medicine Creek, Lyman and Jones Counties, South Dakota from 1999 through 2004.

Site (Assessment Data)	Date	pH (s.u.)	Sample Total	Violation Total	Percent Violation
No Violations	**-**	**-**	**-**	**-**	**-**
			61	0	0.0%
Site (WQM Data)					
WQM-141 (MCT-13)	08/19/1999	9.02			
WQM-141 (MCT-13)	08/21/2000	9.13			
WQM-141 (MCT-13)	06/22/2004	9.01			
WQM-141 (MCT-13)	10/12/2004	9.07			
			55	4	7.3%
Total			**116**	**4**	**3.4%**

- = No data

Only assessment data collected from mainstem Medicine Creek sites (Highway 83 to Kennebec, MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) were used to determine water quality standards violations in the Medicine Creek stream segment (S149, Integrated Report, page 131 (SD DENR 2004)). The WQM site on Medicine Creek at Kennebec, South Dakota (DENR 460141, WQM 141) was also the location of the downstream sampling site during the assessment (MCT-13).

Seasonal Tributary Water Quality

Typically, water quality parameters will vary depending upon season due to changes in temperature, precipitation and agricultural practices. One hundred eighteen tributary water quality samples were collected during the Medicine Creek watershed assessment project. These data were separated seasonally: winter (January – March), spring (April – June), summer (July – September) and fall (October – December). Runoff was recorded at seven sites during the spring and nine sites in the summer and no flow or water quality samples were collected in the fall of 2000. Thirteen sites recorded runoff in the winter of 2001 and all sixteen sampling sites had runoff in the spring of 2001.

Sediment and nutrient concentrations can change dramatically with changes in water volume. Large hydrologic loads at a site may have small concentrations; however, more water usually increases nonpoint source runoff and thus higher loadings of nutrients and sediment may result. Average seasonal tributary concentrations for Medicine Creek by year and season are provided in Table 14 (spring 2000), Table 15 (summer 2000), Table 16 (winter 2001) and Table 17 (spring 2001).

Tributary Concentrations

Table 14. Average spring tributary concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota for 2000.[1,2,4]

Data	Site						
	MCT-1	MCT-1A	MCT-2	MCT-5	MCT-7	MCT-9	MCT-13
Water Temp (°C)	17.75	18.02	16.23	15.00	15.00	17.05	18.08
Dissolved Oxygen (mg/L)	9.45	8.90	9.72	9.80	9.10	10.07	9.79
pH[3] (su)	8.36	8.23	8.21	8.14	7.66	8.45	8.61
Conductivity @ 25° C	-	-	3060	-	-	3953	4040
Fecal Coliform Bacteria (colonies/100 ml)	222	425	1,080	5	400	496	346
E.Coli (colonies/100 ml)	-	-	-	-	-	-	-
Alkalinity (mg/L)	257	252	252	194	139	220	175
Total Solids (mg/L)	3,212	3,210	3,102	2,011	1,074	3,790	3,783
Total Dissolved Solids (mg/L)	3,153	3,137	3,053	1,985	1,030	3,662	3,700
Total Suspended Solids (mg/L)	59	74	48	26	44	128	84
Volatile Total Suspended Solids (mg/L)	8	10	7	9	6	12	12
Ammonia (mg/L)	0.02	0.03	0.04	0.01	0.01	0.04	0.03
Un-ionized Ammonia[3] (mg/L)	0.00214	0.00356	0.00425	0.00036	0.00012	0.00525	0.00818
Nitrate (mg/L)	16.53	30.48	12.97	24.30	1.20	10.80	12.24
TKN (mg/L)	2.40	2.11	2.26	3.26	1.16	2.20	2.27
Organic Nitrogen (mg/L)	2.38	2.09	2.21	3.25	1.15	2.15	2.24
Inorganic Nitrogen (mg/L)	16.55	30.51	13.01	24.31	1.21	10.84	12.27
Total Nitrogen (mg/L)	18.93	32.59	15.22	27.56	2.36	13.00	14.51
Total Phosphorus (mg/L)	0.161	0.138	0.142	0.214	0.275	0.263	0.190
Total Dissolved Phosphorus (mg/L)	0.060	0.029	0.026	0.101	0.151	0.063	0.028
Total Nitrogen toTotal Phosphorus Ratio (mg/L)	124.69	266.83	108.50	128.79	8.58	49.77	104.39

[1] = Highlighted are the highest recorded average concentration or value on mainstem Medicine Creek for a given parameter for the spring of 2000.
[2] = Highlighted are the highest recorded average concentration or value on tributaries to Medicine Creek for a given parameter for the spring of 2000.
[3] = pH and Un-ionized ammonia are highest seasonal concentration not average.
[4] = Seven of the sixteen tributary monitoring sites flowed in the spring of 2000.

Table 15. Average summer tributary concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota for 2000.[1,2,4]

Data	Site								
	MCT-1	MCT-1A	MCT-2	MCT-3	MCT-4	MCT-7	MCT-9	MCT-12	MCT-13
Water Temp (^{o}C)	19.79	-	20.25	14.00	12.20	20.20	20.70	20.11	22.92
Dissolved Oxygen (mg/L)	-	-	-	-	4.87	6.70	8.20	1.63	5.03
pH[3] (su)	8.68	-	8.06	7.70	7.82	8.17	8.19	7.86	8.39
Conductivity @ 25^{o} C	4,640	-	2,955	-	-	1,346	-	200	4,300
Fecal Coliform Bacteria (colonies/100 ml)	5,600	34,000	520	30	5,700	1,700	550	23,000	2,500
E.Coli (colonies/100 ml)	-	-	-	-	-	-	-	-	-
Alkalinity (mg/L)	120	197	207	137	288	183	169	75	142
Total Solids (mg/L)	4,521	4,560	2,640	1,040	702	1,099	3,889	613	4,069
Total Dissolved Solids (mg/L)	4,437	4,506	2,629	1,040	572	1,031	3,817	381	3,992
Total Suspended Solids (mg/L)	84	54	11	-	130	68	72	232	77
Volatile Total Suspended Solids (mg/L)	40	8	4	7	20	14	12	16	19
Ammonia (mg/L)	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.11	0.12
Un-ionized Ammonia[3] (mg/L)	0.00158	0.00000	0.00044	0.00025	0.00043	0.00056	0.00061	0.00310	0.00793
Nitrate (mg/L)	18.20	37.50	2.00	0.10	0.90	0.10	0.10	2.30	0.30
TKN (mg/L)	2.02	2.04	1.17	1.48	1.45	0.95	1.15	1.73	1.59
Organic Nitrogen (mg/L)	2.01	2.03	1.16	1.46	1.42	0.94	1.14	1.62	1.47
Inorganic Nitrogen (mg/L)	18.21	37.51	2.01	0.12	0.93	0.11	0.11	2.41	0.42
Total Nitrogen (mg/L)	20.22	39.54	3.17	1.58	2.35	1.05	1.25	4.03	1.89
Total Phosphorus (mg/L)	0.278	0.128	0.057	0.121	0.887	0.162	0.186	0.822	0.247
Total Dissolved Phosphorus (mg/L)	0.029	0.034	0.014	0.034	0.536	0.038	0.044	0.273	0.034
Total Nitrogen toTotal Phosphorus Ratio (mg/L)	72.73	308.91	55.61	13.06	2.65	6.48	6.72	4.90	7.99

[1] = Highlighted are the highest recorded average concentration or value on mainstem Medicine Creek for a given parameter for the summer of 2000.
[2] = Highlighted are the highest recorded average concentration or value on tributaries to Medicine Creek for a given parameter for the summer of 2000.
[3] = pH and Un-ionized ammonia are highest seasonal concentration not average.
[4] = Nine of the sixteen tributary monitoring sites flowed in the summer of 2000.

Table 16. Average winter tributary concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota for 2001.[1,2,4]

	Site												Byre Lake Watershed[5]
Data	**MCT-1**	**MCT-1A**	**MCT-2**	**MCT-3**	**MCT-4**	**MCT-5**	**MCT-6**	**MCT-7**	**MCT-9**	**MCT-11**	**MCT-12**	**MCT-13**	**MCT-14**
Water Temp (^{o}C)	0.78	0.72	1.08	0.87	1.99	2.23	2.50	2.23	0.67	0.63	6.32	0.60	0.46
Dissolved Oxygen (mg/L)	10.69	10.12	11.34	10.19	10.25	10.11	5.71	10.11	10.41	10.96	8.54	10.55	8.83
pH[3] (su)	7.97	7.97	7.91	8.40	7.98	8.11	8.12	8.11	7.99	8.65	7.95	8.00	8.37
Conductivity @ 25^{o} C	1,508	1,346	587	295	330	277	-	277	1,441	490	247	1,522	574
Fecal Coliform Bacteria (colonies/100 ml)	5	15	45	68	15	10	5	20	100	5	5	1,080	7
E.Coli (colonies/100 ml)	12	19	55	3	11	2	3	6	72	-	4	387	30
Alkalinity (mg/L)	117	117	112	47	66	72	50	55	110	11	74	141	69
Total Solids (mg/L)	1229	1074	1137	250	291	205	149	354	1151	63	269	1910	448
Total Dissolved Solids (mg/L)	1187	1054	1093	235	257	188	137	230	897	56	218	862	417
Total Suspended Solids (mg/L)	43	20	44	15	34	17	12	124	253	7	51	616	32
Volatile Total Suspended Solids (mg/L)	4	3	6	5	5	7	4	10	24	1	4	63	4
Ammonia (mg/L)	0.27	0.26	0.27	0.02	0.10	0.23	0.26	0.20	0.81	0.62	0.48	0.54	0.23
Un-ionized Ammonia[3] (mg/L)	0.00276	0.00292	0.00192	0.00021	0.00157	0.00291	0.00345	0.00253	0.01316	0.02324	0.00588	0.00553	0.00386
Nitrate (mg/L)	15.75	20.00	15.70	0.45	1.00	0.80	0.60	0.90	11.37	0.80	4.40	6.67	1.33
TKN (mg/L)	2.57	2.37	2.24	0.93	0.94	1.36	1.29	1.27	3.14	2.17	1.94	2.12	1.14
Organic Nitrogen (mg/L)	2.30	2.11	1.98	0.91	0.84	1.13	1.03	1.07	2.33	1.55	1.46	1.58	0.91
Inorganic Nitrogen (mg/L)	16.02	20.26	15.97	0.47	1.10	1.03	0.86	1.10	12.18	1.42	4.88	7.21	1.56
Total Nitrogen (mg/L)	18.32	22.37	17.94	1.38	1.94	2.16	1.89	2.17	14.51	2.97	6.34	8.79	2.47
Total Phosphorus (mg/L)	0.301	0.234	0.268	0.313	0.427	0.337	0.565	0.610	0.879	0.390	0.736	0.703	0.386
Total Dissolved Phosphorus (mg/L)	0.171	0.153	0.155	0.251	0.342	0.275	0.479	0.332	0.484	0.345	0.617	0.175	0.282
Total Nitrogen toTotal Phosphorus Ratio (mg/L)	60.30	95.35	66.57	4.38	4.54	6.41	3.35	3.56	19.57	7.62	8.61	36.04	6.77

[1] = Highlighted are the highest recorded average concentration or value on mainstem Medicine Creek for a given parameter for the winter of 2001.
[2] = Highlighted are the highest recorded average concentration or value on tributaries to Medicine Creek for a given parameter for the winter of 2001.
[3] = pH and Un-ionized ammonia are highest seasonal concentration not average.
[4] = Thirteen of the sixteen tributary monitoring sites flowed in the winter of 2001.
[5] = Byre Lake Watershed is below last monitored mainstem site (MCT-13).

Table 17. Average spring tributary concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota for 2001.[1,2,4]

	Site														Byre Lake Watershed[5]	
Data	MCT-1	MCT-1A	MCT-2	MCT-3	MCT-4	MCT-5	MCT-6	MCT-7	MCT-8	MCT-9	MCT-10	MCT-11	MCT-12	MCT-13	MCT-14	MCT-15
Water Temp (^{o}C)	11.44	13.26	10.56	7.12	8.56	5.58	8.50	12.19	13.78	10.69	14.73	3.68	10.13	11.34	12.28	12.05
Dissolved Oxygen (mg/L)	10.43	9.56	10.75	10.62	8.80	10.11	9.99	8.00	10.34	12.75	12.60	13.06	5.59	11.85	10.56	11.10
pH[3] (su)	8.25	8.21	8.43	7.92	8.42	7.96	7.90	8.33	8.51	8.80	8.90	8.13	8.19	8.93	8.60	8.80
Conductivity @ 25^{o} C	2,498	2,167	1,933	757	566	632	522	646	478	1,730	342	194	340	1,584	577	468
Fecal Coliform Bacteria (colonies/100 ml)	960	724	1,200	5	50	70	800	1,224	43	1,243	35	13	14,550	37,614	338	404
E.Coli (colonies/100 ml)	240	438	805	2	45	78	457	490	47	667	21	31	1,225	698	316	-
Alkalinity (mg/L)	208	208	174	91	142	104	114	156	117	173	121	77	148	168	118	107
Total Solids (mg/L)	2,505	2,139	2,351	597	520	532	893	691	385	1,946	244	226	353	1,628	511	391
Total Dissolved Solids (mg/L)	2,281	1,963	2,151	591	419	477	410	493	355	1,475	216	161	275	1,315	434	347
Total Suspended Solids (mg/L)	224	176	200	6	101	55	483	198	30	471	28	66	78	313	78	43
Volatile Total Suspended Solids (mg/L)	13	13	12	2	16	12	47	13	5	23	3	4	8	22	8	7
Ammonia (mg/L)	0.03	0.03	0.03	0.02	0.02	0.06	0.17	0.05	0.07	0.12	0.04	0.03	0.08	0.23	0.04	0.06
Un-ionized Ammonia[3] (mg/L)	0.00127	0.00154	0.00135	0.00024	0.00051	0.00088	0.00230	0.00169	0.00668	0.00389	0.01155	0.00041	0.00119	0.00691	0.00373	0.01310
Nitrate (mg/L)	11.90	24.16	6.04	0.10	0.52	5.90	4.15	0.20	1.80	4.90	0.33	0.65	0.30	5.00	1.15	1.08
TKN (mg/L)	1.73	1.69	1.21	0.59	0.96	1.05	1.52	1.00	1.04	1.72	0.78	0.60	1.72	1.84	0.98	0.93
Organic Nitrogen (mg/L)	1.70	1.67	1.18	0.57	0.94	0.99	1.35	0.95	0.98	1.60	0.75	0.57	1.64	1.61	0.94	1.05
Inorganic Nitrogen (mg/L)	11.93	24.19	6.07	0.12	0.54	5.96	4.32	0.25	1.87	5.02	0.37	0.68	0.38	5.23	1.19	1.18
Total Nitrogen (mg/L)	13.63	25.85	7.25	0.69	1.48	6.95	5.67	1.20	2.84	6.62	1.12	1.25	2.02	6.84	2.13	1.77
Total Phosphorus (mg/L)	0.410	0.116	0.443	0.221	0.354	0.452	1.016	0.446	0.191	0.809	0.128	0.324	0.918	0.773	0.332	0.279
Total Dissolved Phosphorus (mg/L)	0.053	0.044	0.101	0.168	0.171	0.329	0.300	0.132	0.120	0.097	0.077	0.184	0.711	0.194	0.184	0.155
Total Nitrogen toTotal Phosphorus Ratio (mg/L)	108.71	368.74	58.53	3.12	5.04	16.34	6.34	4.55	15.86	51.24	8.95	3.82	4.79	52.33	7.52	6.23

[1] = Highlighted are the highest recorded average concentration or value on mainstem Medicine Creek for a given parameter for the spring of 2001.
[2] = Highlighted are the highest recorded average concentration or value on tributaries to Medicine Creek for a given parameter for the spring of 2001.
[3] = pH and Un-ionized ammonia are highest seasonal concentration not average.
[4] = Sixteen of the sixteen tributary monitoring sites flowed in the spring of 2001.
[5] = Byre Lake Watershed is below last monitored mainstem site (MCT-13).

Four violations in pH have been recorded in Medicine Creek in the past five years, all during routine WQM monthly monitoring (Table 13); while no violations were recorded at any mainstem Medicine Creek sampling site during the assessment. The overall violation percentage rate for pH was 3.4 percent which is below the listing criteria. Generally, pH does not appear to be problem in Medicine Creek.

The dissolved oxygen standard applies to beneficial use standard (6) warmwater marginal fish life propagation waters ($\geq$ 4.0 mg/L) and (8) limited contact recreational waters ($\geq$ 5.0 mg/L) only applies to mainstem Medicine Creek. Two violations (one assessment and one WQM) were recorded in long term dissolved oxygen concentrations for mainstem Medicine Creek (Table 11). During the assessment, five dissolved oxygen concentrations were below the standard of less than or equal to five milligrams per liter. However, four of the five samples were collected at monitoring sites outside (two at MCT-4 and two at MCT-12) mainstem Medicine Creek where the standard does not apply. The overall violation percentage was 1.7 percent and not considered a problem in this watershed.

Fecal coliform bacteria originate in waste material from warm-blooded animals and usually indicate the presence of animal or human wastes. Long term and assessment data indicate fecal coliform is a problem in mainstem Medicine Creek (Table 12). Average fecal coliform concentrations were highest in the spring of 2001 at MCT-13 (374,614 colonies/100 ml and were also high in the summer of 2000 (34,000 colonies/100 ml) at MCT-1A (Table17 and Table 15). Winter livestock feeding areas in and around mainstem Medicine Creek, cattle having unlimited access to the Creek, wildlife and agricultural practices were the most likely sources of sporadic increased fecal coliform counts. A fecal coliform TMDL was developed for Medicine Creek and can be found in Appendix G.

Medicine Creek data indicate conductivity and total dissolved solids (TDS) are highly correlated (82 percent of the variability in conductivity is explained by TDS concentrations) in mainstem Medicine Creek (Figure 12). Medicine Creek is listed in the 2004 South Dakota Integrated Report as violating TDS and conductivity standards. Current and long term data for conductivity and TDS confirm it is a problem in Medicine Creek (Table 8 and Table 9). Average conductivity and TDS concentrations and values were high in the spring and summer of 2000 when flows (discharge) were lowest (Table 14 and Table 15). Average conductivity value was highest in the summer of 2000 at 4,640 µS/cm at MCT-1 (average exceeds the beneficial use standard (4,375 µS/cm)), while TDS concentrations were highest in the summer of 2000 at 4,506 mg/L at MCT-1A (Table 15). Conductivity and TDS were also high in the spring of 2000 at MCT-13. Low flow conditions were generally higher in conductivity and TDS in Medicine Creek.

During the assessment, mainstem Medicine Creek concentrations in total suspended solids (TSS) exceeded water quality standards and overall long term TSS data (assessment and WQM) water quality standards were exceeded (Table 10). Increased TSS standards exceedance concentrations in assessment data may be due to most water quality samples during the study were collected during high water conditions and were considered event based samples, while WQM samples are collected monthly and seldom represent in event based sampling. Increased flow (discharge) increases bedload and sediment transport (Allen 1995)

Average nitrate-nitrite, inorganic nitrogen and total nitrogen concentrations were highest during all sampling seasons (spring 2000, summer 2000, winter 2001 and spring 2001) at MCT-1A Tables 14 through Table 17). Most measured average nitrogen parameters (ammonia, nitrate-nitrite, inorganic nitrogen and total nitrogen) had the highest seasonal concentrations at mainstem Medicine Creek sampling sites (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13). However, average un-ionized ammonia in the winter and spring of 2001 were highest at MCT-11 and MCT-15 (tributaries to Medicine Creek), respectively (Table 16 and Table 17). Average Total Kjeldahl Nitrogen (TKN) and organic nitrogen concentrations were highest at MCT-5 (upper Nail Creek) in the spring of 2000 (Table 14). Total nitrogen to total phosphorus ratios were consistently the highest at MCT-1A throughout all sampling seasons. This correlates to MCT-1A having the highest nitrogen species concentrations in the watershed.

Most average seasonal total phosphorus and total dissolved phosphorus concentrations were higher in tributaries to mainstem Medicine Creek, with the exception being at MCT-9 in the winter of 2001 (Table 16).

Seasonalized Tributary Hydrologic Loadings

Fourteen tributary monitoring sites were set up on Medicine Creek from Vivian to Kennebec, South Dakota in the spring of 2000. Two additional sites were set up in the Byre Lake watershed which discharges into Medicine Creek below Kennebec and was included as additional monitored discharge to Medicine Creek. All sites were monitored approximately 400 days from April 2000 through May 2001 excluding the winter months.

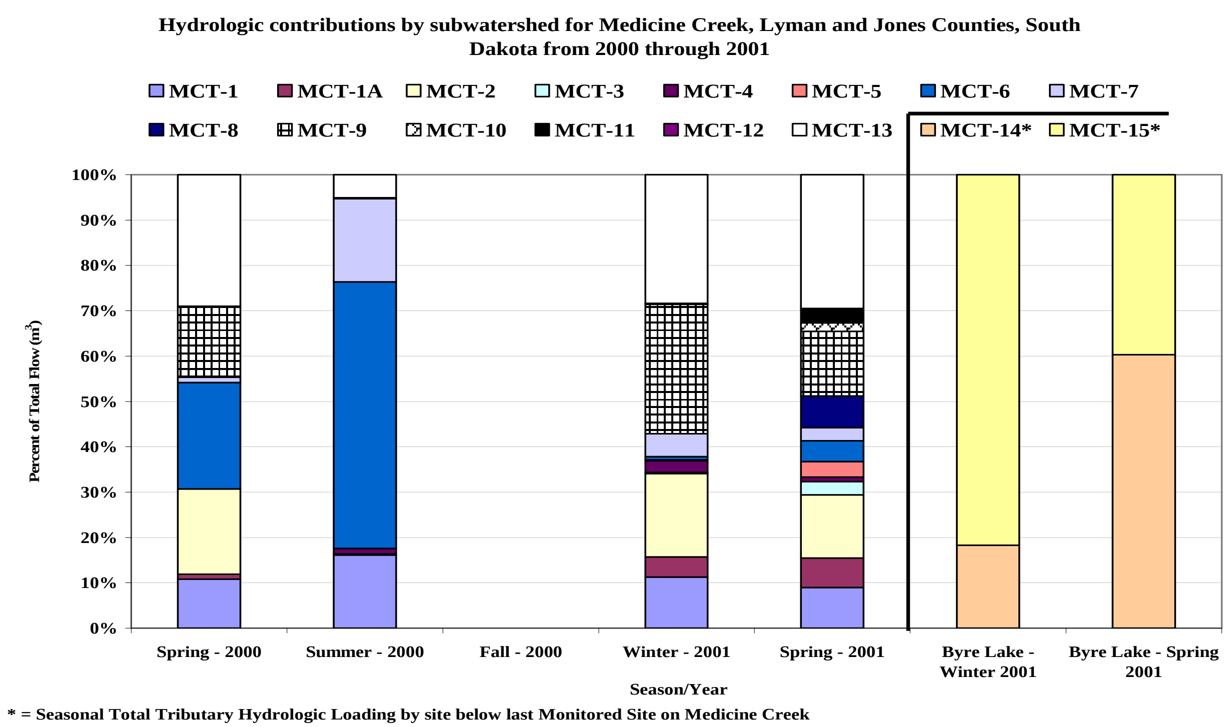


Figure 5. Seasonal hydrologic loading percentage by tributary monitoring site for Medicine Creek and Byre Lake, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 18. Seasonal hydrologic loading percentage by tributary monitoring site for Medicine Creek and Byre Lake, Lyman and Jones Counties, South Dakota from 2000 through 2001.

	Sub-watershed			Seasonal Hydrologic Loading			Export Coefficient	
Location	**Acres**	**Site**	**Season**	**Meters^3**	**Acre-feet**	**Percent**	**Meters^3**	**Acre-feet**
Medicine Creek	**55,556**	**MCT-1**	**Spring - 00**	505,000	409.05	6.04%	9.09	0.007
			Summer - 00	67,000	54.27	0.80%	1.21	0.001
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	3,437,000	2,783.97	41.13%	61.87	0.050
			Spring - 01	4,347,000	3,521.07	52.02%	78.25	0.063
		MCT-1	**Total**	**8,356,000**	**6,768.36**	**100.00%**	**150.41**	**0.122**
Medicine Creek (North Fork)	**32,106**	**MCT-1A**	**Spring - 00**	51,000	41.31	1.12%	1.59	0.001
			Summer - 00	0	0.00	0.00%	0.00	0.000
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	1,339,000	1,084.59	29.38%	41.71	0.034
			Spring - 01	3,168,000	2,566.08	69.50%	98.67	0.080
		MCT-1A	**Total**	**4,558,000**	**3,691.98**	**100.00%**	**141.97**	**0.115**
Medicine Creek	**22,455**	**MCT-2**	**Spring - 00**	879,000	711.99	6.64%	39.14	0.032
			Summer - 00	1,000	0.81	0.01%	0.04	0.000
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	5,594,000	4,531.14	42.27%	249.12	0.202
			Spring - 01	6,761,000	5,476.41	51.08%	301.09	0.244
		MCT-2	**Total**	**13,235,000**	**10,720.35**	**100.00%**	**589.40**	**0.477**
Stoney Butte Creek	**33,254**	**MCT-3**	**Spring - 00**	0	0.00	0.00%	0.00	0.000
			Summer - 00	0	0.00	0.00%	0.00	0.000
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	88,000	71.28	5.89%	2.65	0.002
			Spring - 01	1,407,000	1,139.67	94.11%	42.31	0.034
		MCT-3	**Total**	**1,495,000**	**1,210.95**	**100.00%**	**44.96**	**0.036**
Stoney Butte Creek	**22,797**	**MCT-4**	**Spring - 00**	0	0.00	0.00%	0.00	0.000
			Summer - 00	5,000	4.05	0.39%	0.22	0.000
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	776,000	628.56	60.48%	34.04	0.028
			Spring - 01	502,000	406.62	39.13%	22.02	0.018
		MCT-4	**Total**	**1,283,000**	**1,039.23**	**100.00%**	**56.28**	**0.046**
Upper Nail Creek	**7,975**	**MCT-5**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	64,000	51.8	3.7	8.03	0.006
			Spring - 01	1,653,000	1,338.9	96.3	207.27	0.168
		MCT-5	**Total**	**1,717,000**	**1,390.7**	**100.00%**	**215.30**	**0.174**

Table 18 (continued). Seasonal hydrologic loading percentage by tributary monitoring site for Medicine Creek and Byre Lake, Lyman and Jones Counties, South Dakota from 2000 through 2001.

	Sub-watershed			Seasonal Hydrologic Loading			Export Coeffficient	
Location	Acres	Site	Season	Meters^3	Acre-feet	Percent	Meters^3	Acre-feet
Nail Creek (Fate Dam Inlet)	**7,451**	**MCT-6**	**Spring - 00**	1,095,000	886.9	28.9	146.96	0.119
			Summer - 00	244,000	197.6	6.4	32.75	0.027
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	227,000	183.9	6.0	30.47	0.025
			Spring - 01	2,224,000	1,800.6	58.7	298.48	0.242
		MCT-6	**Total**	**3,790,000**	**3,069.0**	**100.00%**	**508.66**	**0.412**
Stony Butte Creek	**11,914**	**MCT-7**	**Spring - 00**	55,000	44.55	1.79%	4.62	0.004
			Summer - 00	76,000	61.56	2.48%	6.38	0.005
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	1,525,000	1235.25	49.69%	128.00	0.104
			Spring - 01	1,413,000	1144.53	46.04%	118.60	0.096
		MCT-7	**Total**	**3,069,000**	**2485.89**	**100.00%**	**257.60**	**0.209**
Fate Dam Outlet	**1,932**	**MCT-8**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	0	0	0	0.00	0.000
			Spring - 01	3,379,000	2,736.9	100.0	1,748.96	1.417
		MCT-8	**Total**	**3,379,000**	**2,736.9**	**100.00%**	**1,748.96**	**1.417**
Medicine Creek (Near Presho)	**31,200**	**MCT-9**	**Spring - 00**	732,000	592.92	4.47%	23.46	0.019
			Summer - 00	1,000	0.81	0.01%	0.03	0.000
			Fall - 00	0	0	0%	0.00	0.000
			Winter - 01	8,690,000	7,038.90	53.12%	278.53	0.226
			Spring - 01	6,937,000	5,618.97	42.40%	222.34	0.180
		MCT-9	**Total**	**16,360,000**	**13,251.60**	**100.00%**	**524.36**	**0.425**
Brakke Dam Outlet	**917**	**MCT-10**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	2,000	1.62	0.22	2.18	0.002
			Spring - 01	899,000	728.19	99.78	980.37	0.794
		MCT-10	**Total**	**901,000**	**729.81**	**100.00%**	**982.55**	**0.796**
Brakke Dam West Inlet	**11,678**	**MCT-11**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	36,000	29.19	2.46	3.08	0.002
			Spring - 01	1,425,000	1,155.25	97.54	122.02	0.099
		MCT-11	**Inlet Total**	**1,461,000**	**1,184.44**	**100.00%**	**125.11**	**0.101**

Table 18 (continued). Seasonal hydrologic loading percentage by tributary monitoring site for Medicine Creek and Byre Lake, Lyman and Jones Counties, South Dakota from 2000 through 2001

Location	Sub-watershed Acres	Site	Season	Seasonal Hydrologic Loading Meters^3	Seasonal Hydrologic Loading Acre-feet	Seasonal Hydrologic Loading Percent	Export Coefficient Meters^3	Export Coefficient Acre-feet
Brakke Dam East Inlet	**3,026**	**MCT-12**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	30,000	24.32	21.90	9.91	0.008
			Spring - 01	107,000	86.74	78.10	35.36	0.029
		MCT-12	**Inlet Total**	**137,000**	**111.06**	**100.00%**	**45.27**	**0.037**
Brakke Dam Total Input		**Brakke Dam Inlet Total**		**1,598,000**	**1,295.50**	**100.00%**	**108.68**	**0.088**
Medicine Creek (Monitored Outlet)	**44,097**	**MCT-13**	**Spring - 00**	1,354,000	1,096.74	5.57%	30.71	0.025
			Summer - 00	21,000	17.01	0.09%	0.48	0.000
			Fall - 00	0	0.00	0.00%	0.00	0.000
			Winter - 01	8,622,000	6,983.82	35.45%	195.52	0.158
			Spring - 01	14,325,000	11,603.25	58.90%	324.85	0.263
		MCT-13	**Watershed Total**	**24,322,000**	**19,700.82**	**100.00%**	**551.56**	**0.447**
Grouse Creek (Byre Lake Inlet)	**21,993**	**MCT-14**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	270,890	219.70	3.7	12.32	0.010
			Spring - 01	7,040,134	5,709.76	96.3	320.11	0.260
		MCT-14	**Grouse Creek Total**	**7,311,024**	**5,929.46**	**100.00%**	**332.43**	**0.270**
Grouse Creek (Byre Lake Outlet)	**2,183**	**MCT-15**	**Spring - 00**	0	0	0	0.00	0.000
			Summer - 00	0	0	0	0.00	0.000
			Fall - 00	0	0	0	0.00	0.000
			Winter - 01	1,211,000	981.76	20.7	554.74	0.450
			Spring - 01	4,632,000	3,755.16	79.3	2,121.85	1.720
		MCT-15	**Total**	**5,843,000**	**4,736.92**	**100.00%**	**2,676.59**	**2.170**

Table 19. Cumulative annual hydrologic loading and export coefficients for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

	Sub-watershed Acreage	Hydrologic Loading		Export Coefficient	
Site	**Acres**	**Meters^3**	**Acre-feet**	**Meters^3/acre**	**Acre-feet/acre**
MCT-1	55,556	8,356,000	6,768.36	150.41	0.122
MCT-1A	32,106	4,558,000	3,691.98	141.97	0.124
MCT-2	22,455	321,000	260.01	14.30	0.477
MCT-3	33,254	1,495,000	1,210.95	44.97	0.036
MCT-4	22,797	1,283,000	1,039.23	56.28	0.046
MCT-7	11,914	291,000	235.71	24.43	0.209
MCT-9	31,200	56,000	45.36	1.79	0.425
MCT-5	7,975	1,717,000	1,390.77	215.30	0.174
MCT-6	7,451	2,073,000	1,679.13	278.22	0.412
MCT-8	1,932	3,379,000	2,736.99	194.67	0.158
MCT-11	11,678	1,461,000	1,183.41	125.11	0.101
MCT-12	3,026	137,000	110.97	45.27	0.037
MCT-10	917	901,000	729.81	57.68	0.047
MCT-13	44,097	3,682,000	2,982.42	83.50	0.447
Watershed Total	**286,358**	24,322,000	19,700.82	84.94	0.069
Byre Lake Watershed					
MCT-14	21,993	7,311,024	5,921.93	332.43	0.270
MCT-15	2,183	5,843,000	4,732.83	241.69	0.196
Total Monitored Area	310,534	30,165,000	24,433.65	97.14	0.079
Ungauged Area	79,538				
Total Watershed Area	**390,072**				

Approximately 24.3 million cubic meters (19,701 acre-feet) of water flowed through Medicine Creek past Kennebec during the study. An additional 5.8 million cubic feet (4,733 acre-feet) of water flowed from Grouse Creek (Byre Lake watershed) into Medicine Creek below the last monitored mainstem sampling site at Kennebec. During this study (2000 through 2001), a total monitored discharge of approximately 30.2 million cubic meters (24,434 acre-feet) of water flowed through Medicine Creek into the Lower Brule Reservation and into the Missouri River at Lake Sharpe (Table 19).

The overall tributary export coefficient (amount of water delivered per acre) was 97.1 m^3/acre (0.079 acre-foot/acre). Seasonal, annual export coefficients and seasonal loading percentages for all Medicine Creek and Byre Lake watershed monitoring sites are provided in Figure 5, Table 18 and Table 19.

For spatial reference, sub-watershed locations and area can be compared in Figure 4. The peak hydrologic load for most Medicine Creek sub-watersheds (MCT-1, MCT-1A, MCT-2, MCT-3, MCT-5, MCT-6, MCT-8, MCT-10, MCT-11, MCT-12, MCT-13, MCT-14 and MCT-15) occurred in the spring of 2001. In three sub-watersheds (MCT-4 (Stony Butte Creek), MCT-5 (Upper Nail Creek) and MCT-9 (Medicine Creek near Presho)), peak seasonal hydrologic loading occurred in the winter (March) of 2001 (Table 18).

Tributary Water Quality and Loadings

Dissolved Oxygen

Dissolved oxygen concentrations in most unpolluted streams and rivers remain above 80 percent saturation. Solubility of oxygen generally increases as temperature decreases and decreases with decreasing atmospheric pressure (either by a change in elevation or barometric pressure, Hauer and Hill, 1996). Stream morphology, turbulence and flow can also have an effect on oxygen concentrations. Dissolved oxygen concentrations are not uniform within or between stream reaches. Upwelling of interstitial waters at the groundwater and streamwater mixing zone (hyporheic zone) or side flow of ground waters may create patches within a stream reach where dissolved oxygen concentrations are significantly lower than surrounding water (Hauer and Hill, 1996). Medicine Creek dissolved oxygen concentrations median 9.98 mg/L (average, 9.85 mg/L) during this study.

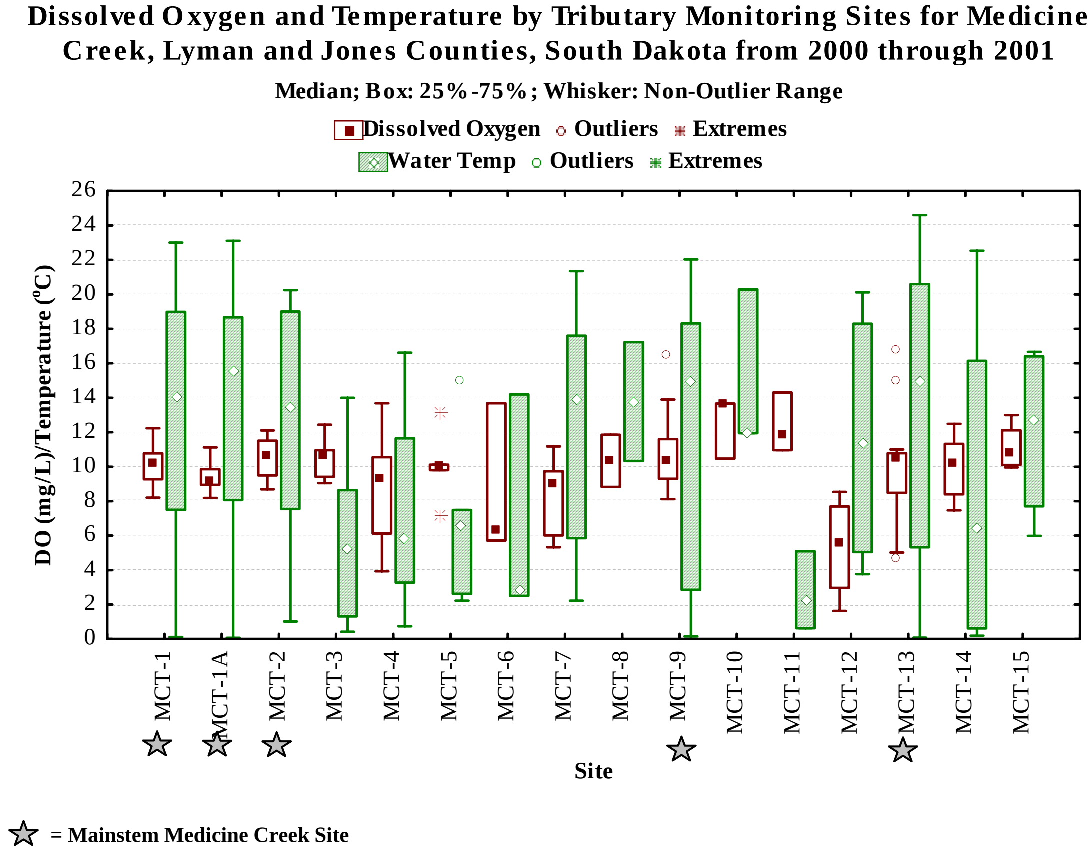


Figure 6. Dissolved oxygen concentrations and temperature by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Seasonal and daily concentrations of chemicals (biotic and abiotic) in water can also affect dissolved oxygen concentrations. Higher chemical concentrations also increase Biochemical and Sediment Oxygen Demand (BOD and SOD). These processes use oxygen in the system to break down or convert organic and inorganic compounds.

The maximum dissolved oxygen concentration in Medicine Creek was 16.71 mg/L. This sample was collected at site MCT-13 on May 14, 2001 (Figure 6 and Appendix D). The minimum dissolved oxygen concentration was 1.63 mg/L at MCT-12 on July 11, 2000 (Appendix D). As previously stated, the dissolved oxygen standard only applies to mainstem Medicine Creek (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13). Long-term violations in dissolved oxygen only comprised 1.7 percent of all samples collected from 1999 through 2004 (two violations in 117 samples (Table 11)). Overall, dissolved oxygen concentrations are not considered a problem in Medicine Creek. Overall dissolved oxygen concentrations were significantly different between monitoring sites (Table 4); however, not significant enough (p=0.018) for detecting differences using mean separation procedures (Appendix B, Table B-2).

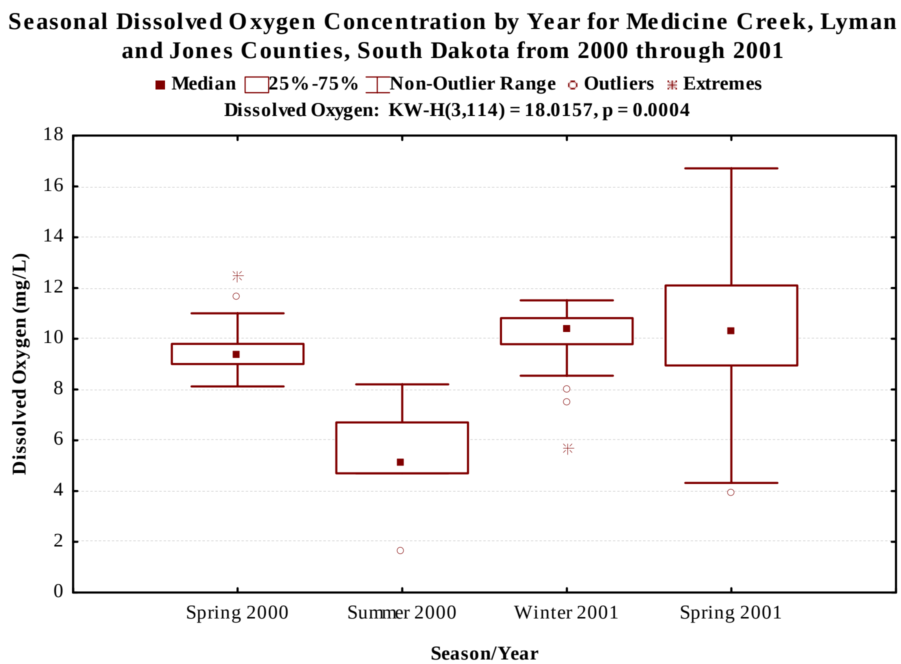


Figure 7. Seasonal comparison of dissolved oxygen by year for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001

Seasonal tributary dissolved oxygen concentrations by year indicate the summer of 2000 was significantly lower (p=0.004) than all other seasons during the project (Figure 7) and was attributed to low flow conditions. Figure 8 shows dissolved oxygen concentrations between mainstem Medicine Creek and tributaries to Medicine Creek were statistically similar (p>0.05).

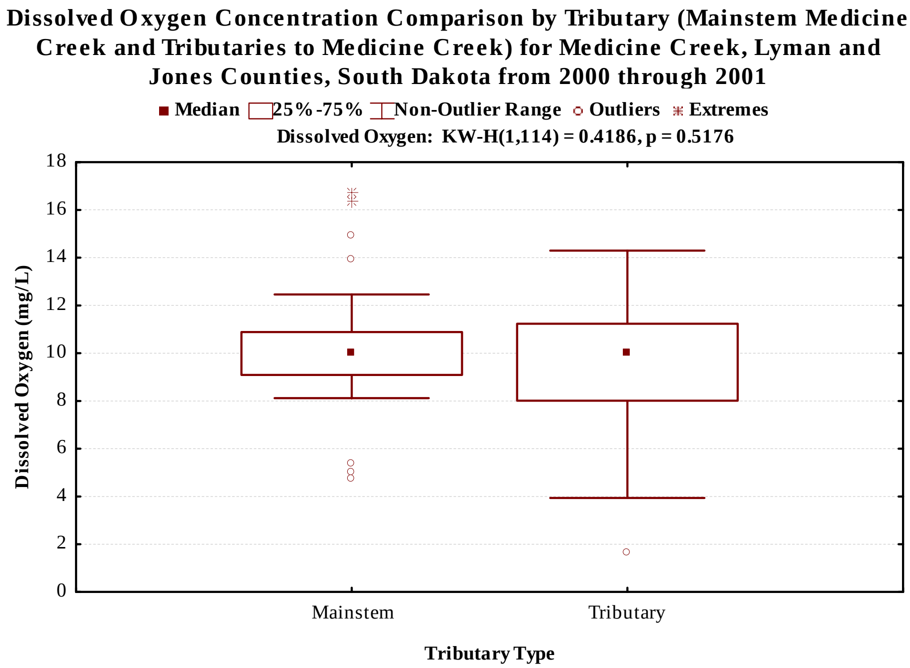


Figure 8. Dissolved Oxygen Concentration Comparison by Tributary (Mainstem Medicine Creek and Tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

pH

pH is a measure of hydrogen ion concentration, the more free hydrogen ions, (i.e. more acidic) the lower the pH in water. The pH concentrations in Medicine Creek were not extreme in any tributary sample. The relatively high alkalinity concentrations in Medicine Creek work to buffer dramatic changes in pH. Lower pH values are normally observed during increased decomposition of organic matter.

pH concentrations in Medicine Creek had a maximum pH of 8.93 su and a minimum pH of 7.58 su (Appendix D). Generally throughout this project, pH concentrations were higher at MCT-8 (Fate Dam outlet), MCT-10 (Brakke Dam outlet) and MCT-15 (Lake Byre outlet) than other tributary sampling sites (Figure 9). Overall pH values were significantly different between monitoring sites (Table 4); however, not significant enough (p=0.0058) for detecting differences using mean separation procedures (Appendix B, Table B-3).

Table 14 through Table 17 lists seasonal maximum pH concentrations by tributary sampling site. This may be attributed to increased algal concentrations in Fate Dam, Brakke Dam and Byre Lake discharging back into their respective tributary. Algae are known to increase pH in lakes (Wetzel, 2001 and Cole, 1988).

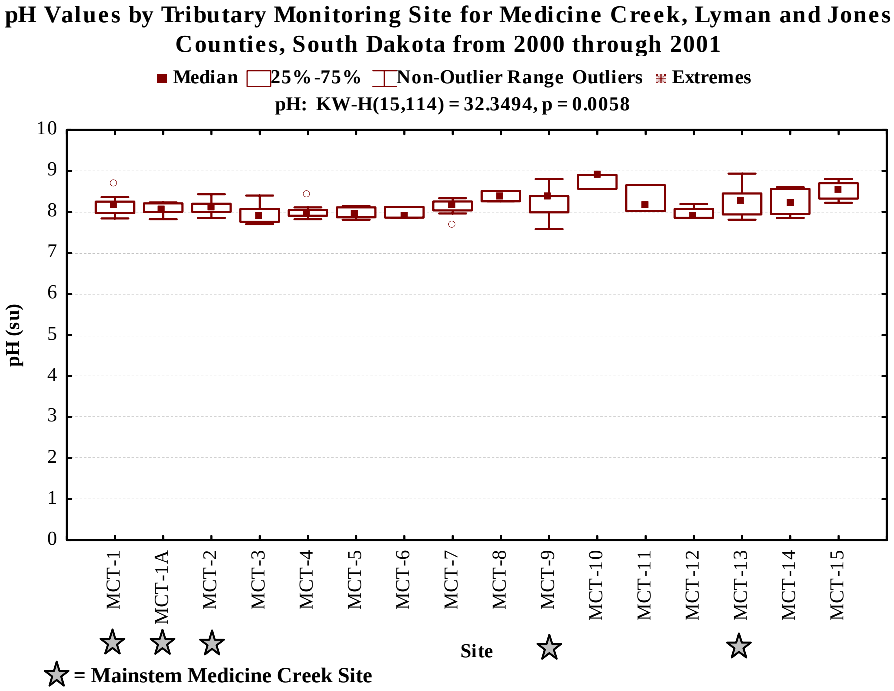


Figure 9. Median, quartile and range for pH concentrations by tributary monitoring site for Medicine Creek and Byre Lake, Lyman and Jones Counties, South Dakota from 2000 through 2001.

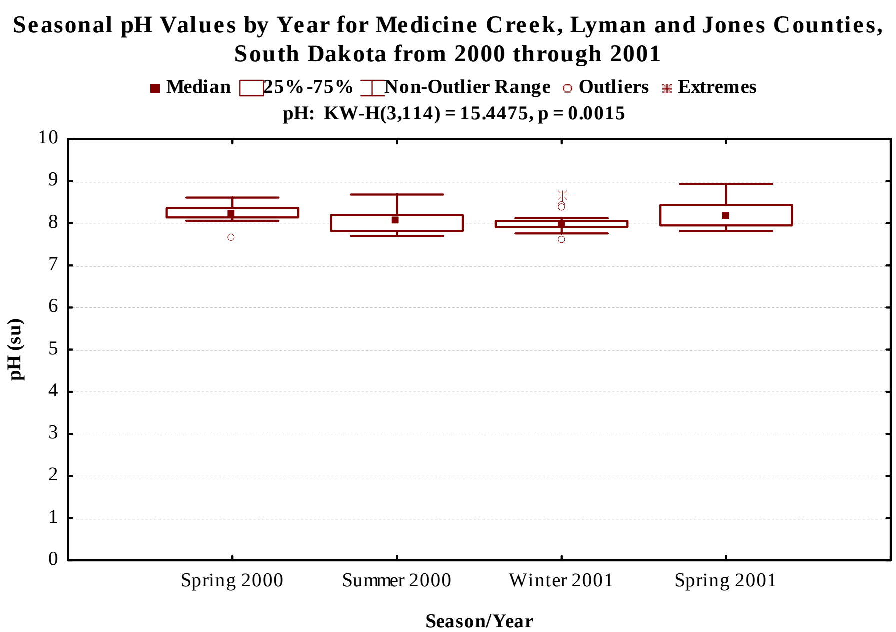


Figure 10. Median, quartile and range for seasonal pH values for Medicine Creek, Lyman County, South Dakota from 2000 through 2001.

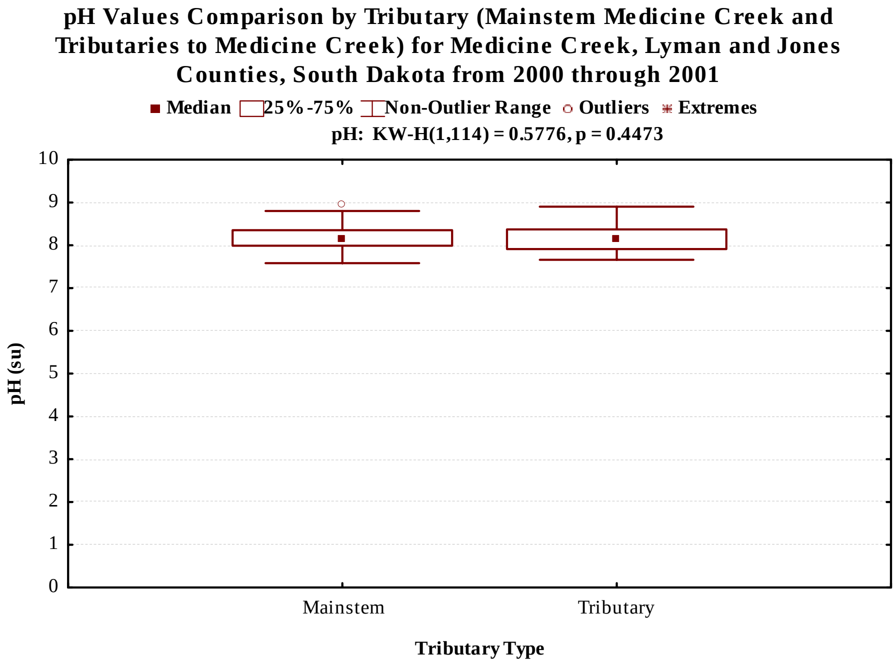


Figure 11. pH value comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Four violations in pH have been recorded in Medicine Creek in the past five years, all during routine WQM monthly monitoring (Table 13); while no violations were recorded at any Medicine Creek sampling site during the assessment. The overall pH violation rate for Medicine Creek was 3.4 percent (4 violations/116 observations) well below the 10 percent listing criteria. Seasonal tributary pH values by year indicate the winter of 2001 was significantly lower ($p=0.0015$) than spring of 2000 and was also significantly lower than spring of 2001 (Figure 10). Medicine Creek pH values between mainstem Medicine Creek and tributaries to Medicine Creek were statistically similar ($p>0.05$) during this study (Figure 11).

Specific Conductance (Conductivity @ 25^{o} C)

Conductivity is a measure of electrical conductance of water, and an approximate predictor of total dissolved ions. Increased ion concentrations reduce the resistance to electron flow; thus, differences in conductivity result mainly from the concentration of charged ions in solution, and to a lesser degree, ionic composition and temperature (Allan, 1995). The temperature of an electrolyte affects ionic velocities and conductance increases approximately 2 percent per degree Celsius (Wetzel, 2001). Specific conductance is conductivity adjusted to temperature (25º C) and is reported in micro-Siemens/centimeter (µS/cm). Surface water quality rules (Article 74:51) lists specific conductance as conductivity @ 25° C with values in µmhos/cm; for this report, conductivity @ 25° C will be referred to as specific conductance with values in µS/cm (updated units).

Typically, there is a good relationship between total dissolved solids (TDS) and specific conductance. Current data indicate an excellent relationship (R^2 = 0.9877) between specific conductance and total dissolved solids for tributaries to Medicine Creek, or 98.77 percent of the variability in conductivity is explained in total dissolved solids (Figure 12). The relationship for specific conductance and total dissolved solids in mainstem Medicine Creek was also extremely good with an R^2 = 0.8222 (Figure 12).

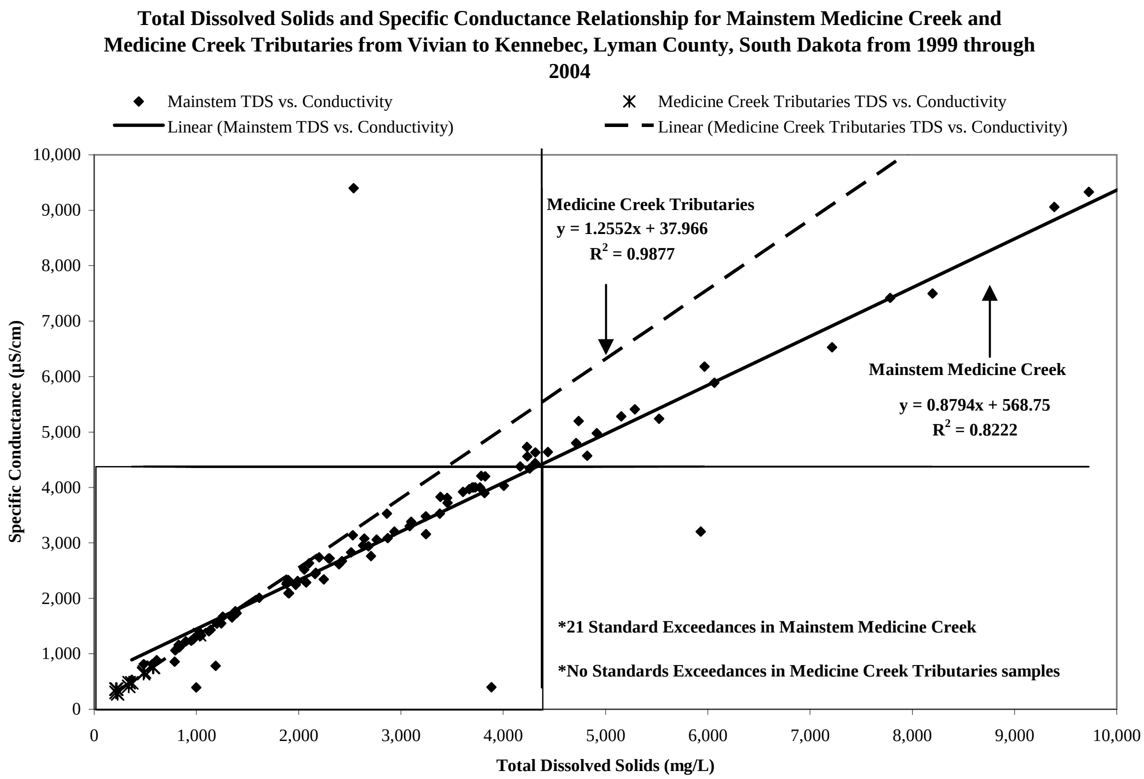


Figure 12. Relationship of total dissolved solids to specific conductance (µS/cm) for Medicine Creek tributaries and mainstem Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The relationship between specific conductance and TDS concentrations by water quality monitoring site can be seen in Figure 13. Specific conductance trends by tributary monitoring site are mirrored by TDS concentrations with mainstem Medicine Creek sites higher than Medicine Creek tributaries.

Specific conductance values within tributaries to Medicine Creek never exceeded 1,346 µS/cm while mainstem Medicine Creek sites MCT-1 and MCT-13 exceeded assigned beneficial use based water quality standards (4,375 µS/cm) twice during the assessment (Figure 13 and Table 8). The MCT-13 monitoring site near Kennebec, South Dakota is also a statewide Water Quality Monitoring site (WQM-141) and is monitored monthly. Twenty WQM samples collected at MCT-13 since 1999 violated water quality standards for specific conductance (Table 8).

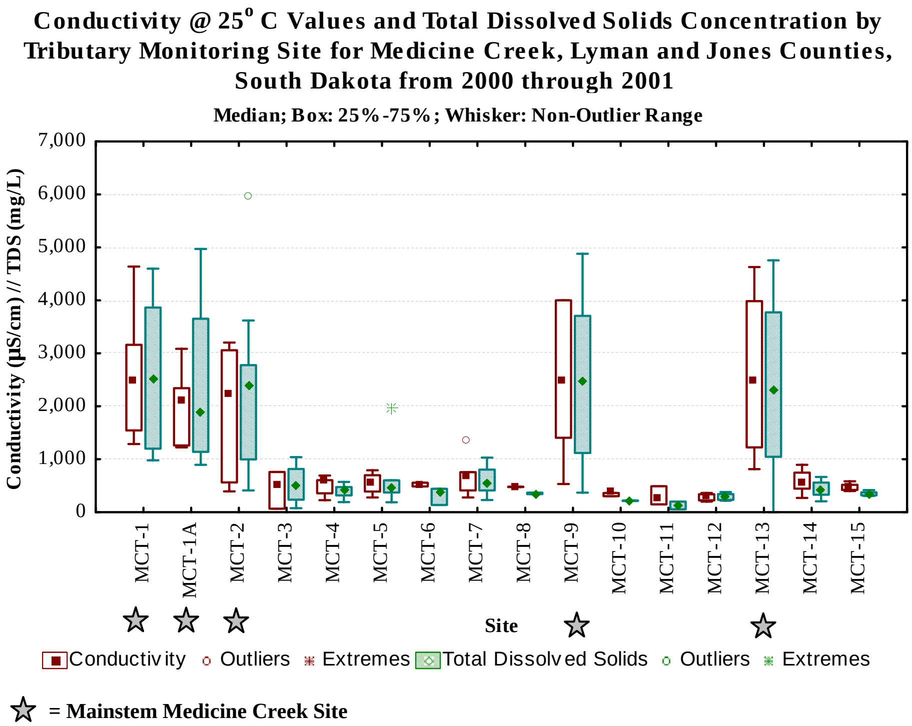


Figure 13. Median, quartile and range for specific conductance values by tributary monitoring site for Medicine Creek and Byre Lake (MCT-14 and MCT-15), Lyman and Jones Counties, South Dakota from 2000 through 2001.

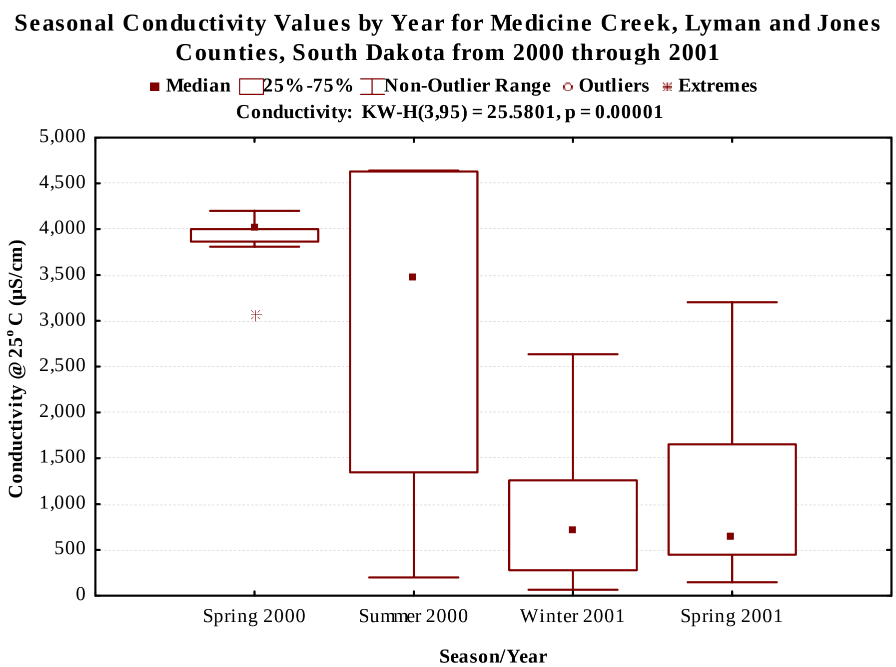


Figure 14. Seasonal comparison of specific conductance the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Specific conductance values were statistically different between sampling sites with MCT-1, MCT-9 and MCT-13 significantly higher than MCT-12 (p=0.01) and MCT-4 was significantly lower (p=0.048) than MCT-13 (Appendix B, Table B-1). Seasonal conductivity values by year show spring of 2000 samples were significantly higher (p=0.0000) than the winter of 2001 and the spring of 2001 samples (Figure 14). Medicine Creek specific conductance values between mainstem Medicine Creek and tributaries to Medicine Creek were statistically different (p=0.0000) with mainstem Medicine Creek specific conductance values significantly higher than tributaries to Medicine Creek (Figure 13 and Figure 15).

Specific conductance values in tributaries to Medicine Creek (MCT-3, MCT-4, MCT-5, MCT-6, MCT-7, MCT-8, MCT-10, MCT-11, MCT-12, MCT-14 and MCT-15) were below the beneficial use standard for conductivity @ 25^o C (Figure 13). Medicine Creek is listed in *The 2004 South Dakota Integrated Report for Surface Water Quality Assessment* (305(b) report and 303(d) list combined) as impaired for conductivity and TDS (2004 Integrated Report (page 131)). Data indicate that monitored tributaries to Medicine Creek do not contribute high conductivity values or TDS concentrations to mainstem Medicine Creek (Figure 13). Discharge from monitored tributaries to Medicine Creek may improve (lower) mainstem Medicine Creek specific conductance values and TDS concentrations by way of dilution. TDS concentrations and specific conductance values for Medicine Creek collected during this project are provided in Appendix D.

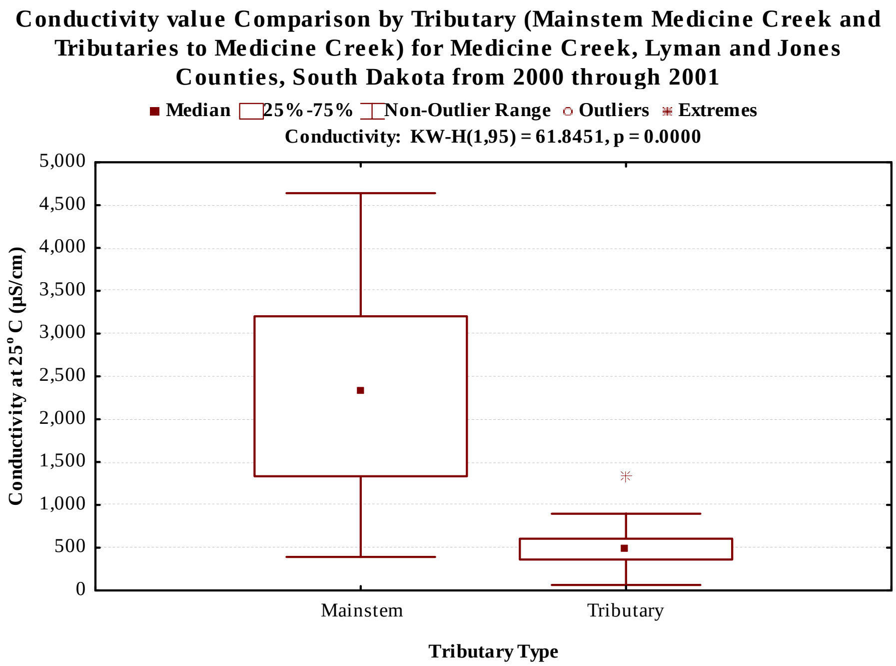


Figure 15. Specific conductance value comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

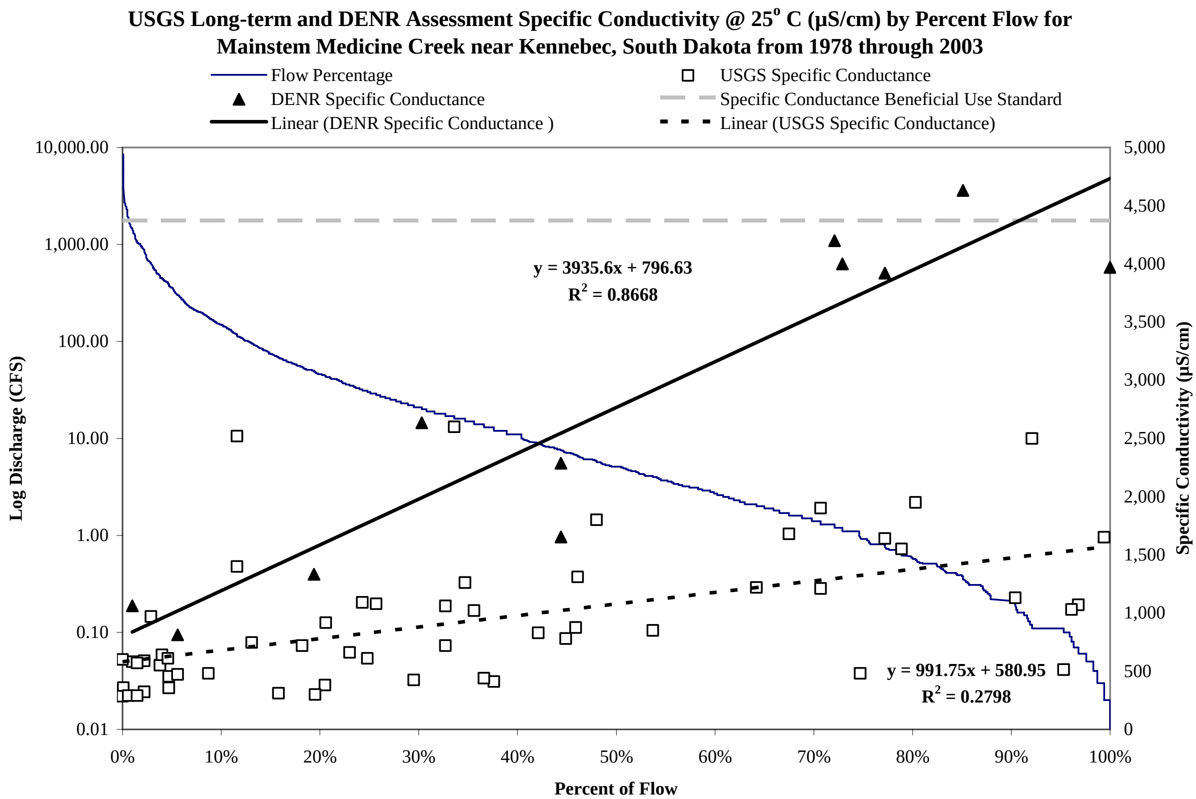


Figure 16. USGS Long-term and DENR Assessment Conductivity @ 25° C (µS/cm) by percent flow for mainstem Medicine Creek (MCT-13) near Kennebec, Lyman County, South Dakota from 1978 through 2004.

United States Geological Survey (USGS) maintained monitoring site (06442500) on Medicine Creek at Kennebec, South Dakota from July 1954 through September 1990. This site was located 1.37 river kilometers (0.85 miles) upstream of assessment site MCT-13 (water quality monitoring site WQM-141). USGS collected 13,240 days of stage and discharge data, this data was used to develop a flow percentage graph to determine at what flow percentage (rate) specific conductance values occur (Figure 16). Fifty-eight USGS water quality samples were collected from this site that included specific conductance sampling. In September 1990, the USGS site was shut down; however, periodic water quality monitoring which included specific conductance (conductivity @ 25° C) still occurred. Eleven of the 58 samples USGS collected have been collected since shut down. USGS specific conductance values were coupled with the daily discharge from that day and plotted on the flow percentage graph. USGS specific conductance values were negatively correlated with discharge (flow), although slightly (-0.29). This indicates as discharge increases specific conductance values decrease. Geological Survey specific conductance data was collected from March of 1978 through May of 2003 with values ranging from 284 to 2,600 (µS/cm). These values are below the assigned beneficial use water quality standard for specific conductance (conductivity @ 25° C, ≤ 4,375 µS/cm). The linear relationship of specific conductance to flow (R^2) was also low at 0.28, with only 28 percent of the variation in specific conductance is explained by flow (Figure 16).

Since this site was 1.37 stream kilometers upstream of MCT-13, assessment specific conductance samples and corresponding daily discharge data were plotted on USGS flow percentage graph. Long-term WQM data (59 specific conductance samples) has also been collected from this site; however, WQM sampling protocols do not collect flow/discharge measurements so these data could not be used for flow relationships and analysis. Eleven specific conductance and corresponding flow/discharge samples were collected during the Medicine Creek watershed assessment project from April 2000 through May 2001. Flow percentage were calculated for each specific conductance point and plotted on the flow percentage graph based on log-term USGS flow data. Similar to USGS data, SD DENR specific conductance values were negatively correlated with discharge (-0.44) suggesting higher specific conductance values at lower flows. SD DENR specific conductance values at MCT-13 ranged from 813 to 4,630 (µS/cm). One value was above the assigned beneficial use water quality standard for specific conductance (conductivity @ 25^o C, $\leq$ 4,375 µS/cm). The linear relationship of specific conductance to flow (R^2) was high at 0.87, with 87 percent of the variation in specific conductance values was explained by discharge/flow (Figure 16). Due to violations in assigned beneficial use based water quality standards in specific conductance and the strong relationship between specific conductance and flow further investigation was initiated.

Medicine Creek watershed flows through the Pierre Shale formation (Upper Cretaceous) which is made up of blue-gray to dark gray, fissile to blocky shale with persistent beds of bentonite, black organic shale and light-brown chalky shale. Pierre Shale contains minor sandstone, conglomerate and abundant carbonate and ferruginous concretions. Thickness of this formation can be up to 823 meters (2,700 feet).

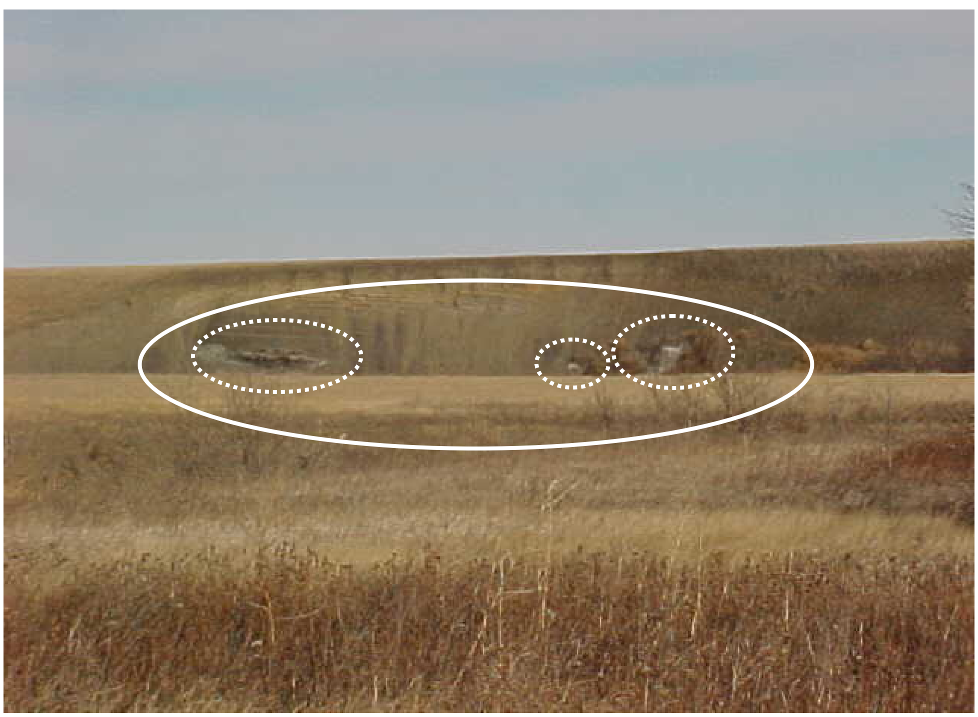


Figure 17. Pierre Shale outcrop (solid circle) with alkali seeps (dashed circles) along mainstem Medicine Creek west of Kennebec, South Dakota 2004.

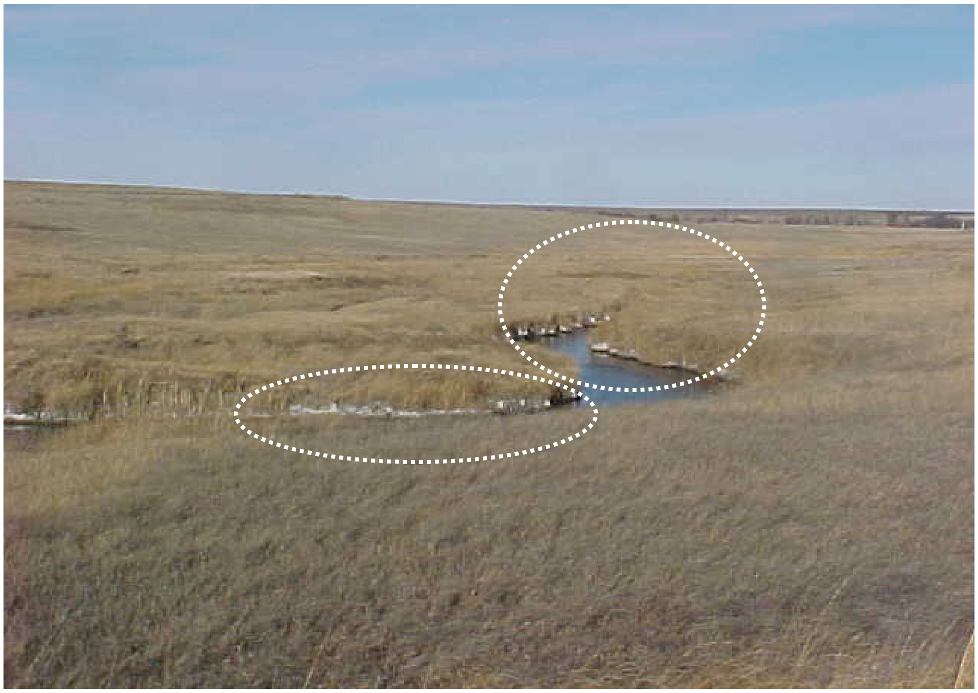
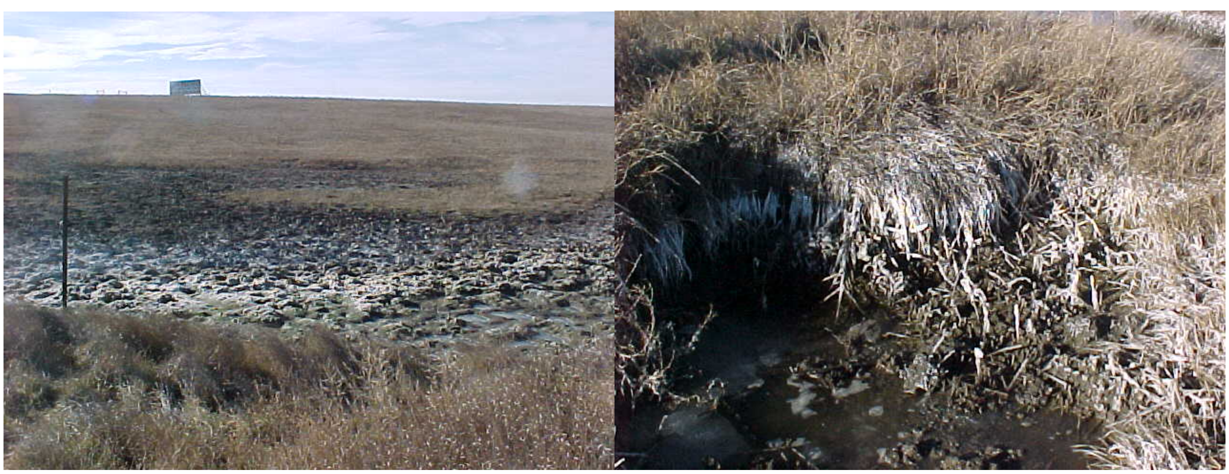


Figure 18. Alkali/saline seeps and deposits along alluvial deposits (dashed circles) in a tributary to Medicine Creek west of Kennebec, South Dakota 2004.



Seep Site - Anderson 1 **Seep Site – Urban 1**

Figure 19. Seep sampling sites Anderson 1 and Urban 1 adjacent to several Medicine Creek tributaries, Lyman County, South Dakota 2004.

Many alkali seeps and springs were located in Pierre Shale outcrops along mainstem Medicine Creek (Figure 17) and in major tributaries (Figure 18) to Medicine Creek (especially in the lower portion of the study reach west of Kennebec, South Dakota). Two flowing seeps/springs were located in lower Medicine Creek adjacent to several tributaries that influence Medicine Creek

(Figure 19). One water quality sample was collected from both sites to determine potential water quality impacts to Medicine Creek especially in specific conductance and TDS concentrations. Seep sites Urban 1 and Anderson 1 were located downstream (east) of MCT-9 and were south of mainstem Medicine Creek just off unmonitored tributaries to Medicine Creek. Both seep sites were located adjacent to and impacted these unmonitored tributaries and eventually Medicine Creek (Figure 19). Evidence of alkali/saline seeps and deposits occur all along mainstem Medicine Creek (Lyman and Jones Counties) and were more prevalent throughout tributaries to Medicine Creek between MCT-9 (Presho and MCT-13 (Kennebec). These areas contribute to high specific conductance values and TDS concentrations, especially in low flow conditions (Figure 16). Discharge plays a major role in TDS concentrations and specific conductance values by reducing existing concentrations of TDS and specific conductance with increasing discharge (dilution effect). All specific conductance values and TDS concentrations in monitored tributaries to Medicine Creek (MCT-3, MCT-4, MCT-5, MCT-6, MCT-7, MCT-8, MCT-10, MCT-11, MCT-12, MCT-14 and MCT-15) were significantly lower ($p=0.000$) than mainstem sites (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) suggesting mainstem Medicine Creek has down cut more into the Pierre Shale formation and exposed more seeps and springs contributing to higher concentrations at low flow (groundwater based) conditions. Figure 20 shows channel evolution in mainstem Medicine Creek below Presho is in a Stage III (widening with bank failures) trying to reach equilibrium (Schumm et al, 1984).

Figure 20. Mainstem Medicine Creek showing bank failures and widening between Presho and Kennebec, Lyman County, South Dakota in 2004.

This situation may have exposed more of mainstem Medicine Creek to lateral groundwater flow creating seeps and upwelling of interstitial waters at the groundwater streamwater mixing zone (hyporheic zone) resulting in extended flow duration during low flow drought conditions. Data supports this scenario with discharge (flow) in mainstem Medicine Creek sites (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) during the spring and summer of 2000 with limited rainfall and relatively little flow from contributing tributaries (Table 18). The majority of violations in assessment TDS concentrations and WQM specific conductance values occurred during low flow groundwater and seep dominated conditions in the spring and summer of 2000 (Table 8 and Table 9).

Table 20. Comparison of Freeman Dam well and seep samples (September 1997) to Medicine Creek seep samples (December 2004).

	Freeman Dam Wells					Freeman Dam Seeps		Medicine Creek Seeps	
Sampling site	R20-97-40	R20-97-41	R20-97-42	R20-97-43	R20-97-41 (Duplicate)	Seep # 4	Seep # 12 (Near nest)	Anderson 1	Urban 1
Date Collected	9/15/1997	9/16/1997	9/16/1997	9/16/1997	9/16/1997	9/15/1997	9/16/1997	12/16/2004	12/16/2004
Selenium; ug/L	4,172	3,290	730	2,294	3,401	8,140	4,290	3,051	74.8
Nitrate; mg/L	752	870	216	436	885	1,066	1,225	184	<0.1
Nitrite; mg/L	0.12	0.1	17.14	16.16	0.09	6.07	0.94	---	---
Ammonia; mg/L	<0.02	0.17	0.27	---	0.55	0.77	0.21	---	---
Specific Conductivity; (µS/cm)	9,490	11,000	7,770	---	11,000	15,300	132,000	16,400	11,973
Total Dissolved Solids (mg/L)	9,689	11,644	7,352	8,402	11,454	17,075	14,196	17,000	52,500
Sulfate (mg/L)	3,263	3,997	4,006	---	3,966	6,485	3,750	11,440	37,100
Total Phosphate (mg/L)	0.64	1.67	0.843	---	1.19	0.124	0.143	---	---
Ortho Phosphate (mg/L)	<0.005	0.008	0.068	---	0.011	0.025	0.005	---	---
Chloride (mg/L)	167	273	143	---	271	348	392	---	---
Total Iron (mg/L)	0.06	0.06	<0.06	<0.06	0.06	0.15	0.08	---	---
Manganese (mg/L)	0.03	0.05	0.08	0.43	0.04	0.03	0.55	---	---
Calcium (mg/L)	585	587	383	522	627	689	891	110	94.6
Magnesium (mg/L)	464	727	328	294	757	833	575	585	785
Sodium (mg/L)	1,290	1,383	1,294	1,643	1,461	2,806	2,076	4,280	14,560
Potassium (mg/L)	48	44	35	36	46	87	17	---	---
Fluoride (mg/L)	0.51	0.22	0.87	---	0.23	0.36	1.39	2.42	1.38
pH (su)	7.35	7.05	7.34	---	6.98	8.2	7.69	7.88	8.63
Alkalinity (mg/L)	227	320	466	---	324	321	392	520	559
Arsenic (ug/L)	<1.3	<1.3	<1.3	1.3	<1.3	2.3	<1.3	---	---
Boron; mg/L	0.39	1.29	1.45	1.34	1.24	1.14	1.22	---	---
Molybdenum (ug/L)	0.65	0.26	0.83	6.04	0.28	2.86	9.81	---	---
Total Mercury (ug/L)	0.12	0.19	<0.12	0.13	0.21	0.42	0.28	---	---
Nickel (ug/L)	33.4	---	14.3	18.8	17.7	20.3	21.7	---	---
Cobalt (ug/L)	0.84	0.66	0.58	3.07	0.67	0.84	1.4	---	---
Silica; ug/L	4,561	7,187	6,712	4,406	7,576	4,561	4,879	---	---
Strontium (ug/L)	9,760	9,914	6,963	8,253	10,511	12,063	11,733	---	---
Uranium (ug/L)	17.9	9.56	43.8	---	9.61	---	141	---	---

For comparison, sample data from another watershed studied by SD DENR (South Dakota Geological Survey) located in the Pierre Shale formation with violations in specific conductance values and TDS concentrations (selenium, sulfate, sodium and nitrate) was used for comparison (Table 20). Freeman Dam is located in Jackson County, South Dakota and is approximately 45.1 km (28 miles) west of Draper, South Dakota (western extent of Medicine Creek watershed). Four well and two groundwater seep samples were collected at Freeman Dam in September 1997 because of high nitrate, conductivity and selenium concentrations in Freeman Dam (Table 20). Freeman Dam well and seep samples had very high conductivity values, TDS, nitrate, sulfate, sodium and selenium concentrations. Groundwater seeps with high TDS, nitrate concentrations and specific conductance values resulted in high TDS, nitrate concentrations and specific conductance values in Freeman Dam by way of surface and groundwater runoff concentrating in Freeman Dam (Table 20). Thus, under certain conditions and locations, natural alkali/saline seeps in Pierre Shale formations can cause high concentrations of TDS, nitrates, sulfate, sodium and selenium concentrations and specific conductance in receiving waters and should be considered a natural condition.

Medicine Creek seep samples show similar high concentrations of TDS, nitrates, sulfate, sodium and selenium and specific conductance values as did Freeman Dam (Table 20). Data from Freeman Dam and Medicine Creek indicate that are under certain conditions, high TDS, nitrate sulfate, sodium and selenium concentrations and specific conductance values occur and may be common throughout the Pierre Shale formation. Thus, violations in assigned beneficial use based water quality standards in Medicine Creek for specific conductance and TDS concentrations during low flow conditions should be considered a natural condition because geologic conditions create high TDS concentrations that cause high specific conductance values in mainstem Medicine Creek.

SAR (Sodium Adsorption Ratio) was calculated for each seep sample site location to estimate the potential impact the seeps may have on their respective tributaries. The SAR standard applies to all streams of the State. For most waters, the beneficial use based water quality standard for SAR, $\leq$ 10 milliequivalents per liter (me/L) which applies to beneficial use 10-irrigation waters (exception Belle Fourche River where SAR concentrations must be below 6 milliequivalents per liter). SAR results for these samples exceeded the water quality standard (Anderson 1, 36.0 me/L and Urban 1, 107.6 me/L) and suggest that seeps originating in the Pierre Shale formation may have high SAR that impact both tributaries and mainstem Medicine Creek. Typically, routine assessment water quality samples do not include sampling for Sodium (Na^{+}), Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) parameters thus SAR exceedance in the Medicine Creek watershed could not be ascertained. High SAR values in groundwater seeps would be diluted by surface water flows and would not be a concern in mainstem Medicine Creek. Currently, no irrigators have permits to use water from Medicine Creek.

The assigned beneficial use classifications for Medicine Creek (stream segment mainstem Medicine Creek from the mouth of Lake Sharpe to Highway 83 overpass) is warmwater marginal fish life propagation water, limited-contact recreation water, Fish and wildlife propagation, recreation, and stock watering water and irrigation water. Data indicate the beneficial use based water quality standard for specific conductance (conductivity @ 25° C) has been exceeded. Due to natural conditions in the Pierre Shale formation, most high specific conductance violations ($\leq$ 4,375 µS/cm) occur during groundwater and seep dominated low flow/discharge (Table 8).

Based on naturally occurring TDS concentrations in seep and groundwater, Medicine Creek can not meet current water quality standards for specific conductance especially at low flow conditions. Current and long-term data suggest that in the Medicine Creek watershed, high specific conductance (conductivity @ 25° C) values and TDS concentrations occur throughout mainstem Medicine Creek, especially during low flows due to natural (geological) conditions.

Because of the highly significant relationship between specific conductance and TDS (R^2 = 0.82) and that TDS causes high conductivity values in Medicine Creek, water quality standard violations in TDS should also be considered a natural condition.

Total Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7.00 su). These various bicarbonate and carbonate compounds generally originate from dissolution of sedimentary rock (Allan, 1995). Alkalinity in natural environments usually ranges from 20 to 200 mg/L (Lind, 1985).

The median alkalinity in Medicine Creek was 138.0 mg/L (average, 153.7 mg/L). The minimum alkalinity concentration was 11 mg/L and was collected at site MCT-11 on March 13, 2001 while the maximum alkalinity sample (336 mg/L) was collected at site MCT-1A on May 31, 2000 (Figure 21 and Appendix D). Alkalinity concentrations were statistically different (p=0.000) between sampling sites with MCT-3 significantly lower than MCT-1A and MCT-2 while MCT-1A was also significantly higher than MCT-14 (Appendix B, Table B-6). Seasonally, Medicine Creek alkalinity concentrations collected in the winter of 2001 were significantly lower than spring 2000, summer 2000 and spring 2001 while the spring of 2000 was significantly higher than the spring of 2001 (Figure 22). Mainstem Medicine Creek alkalinity concentrations were significantly higher (p=0.0000) than concentrations in tributaries to Medicine Creek (Figure 23).

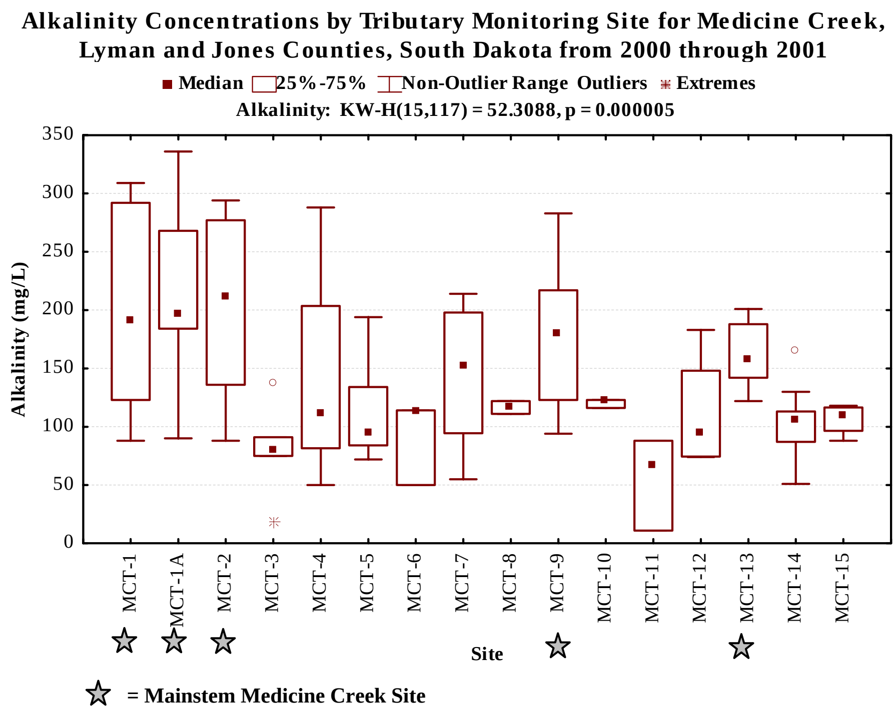


Figure 21. Median, quartile and range for alkalinity concentrations by tributary monitoring site for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

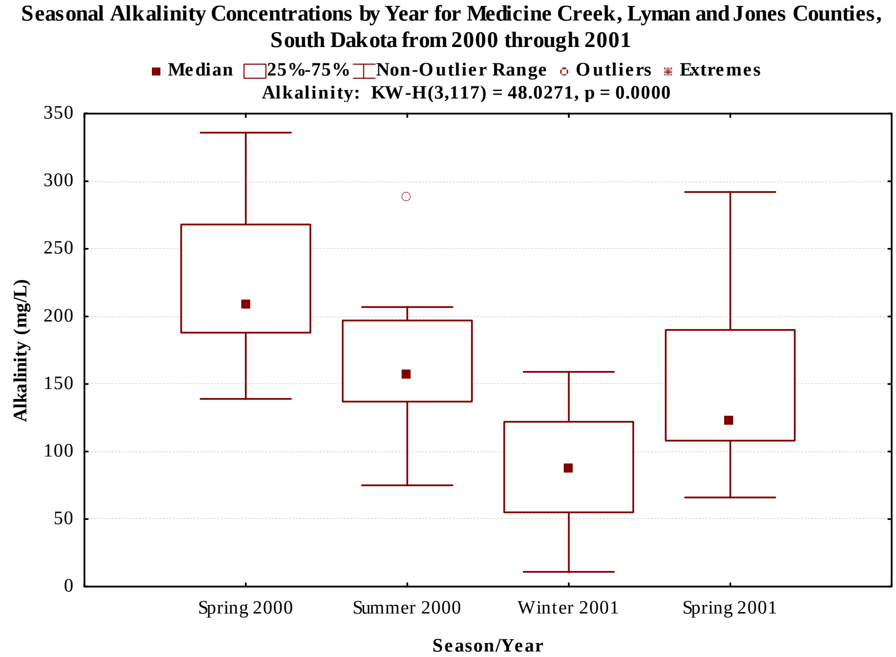


Figure 22. Seasonal comparison of alkalinity concentrations in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

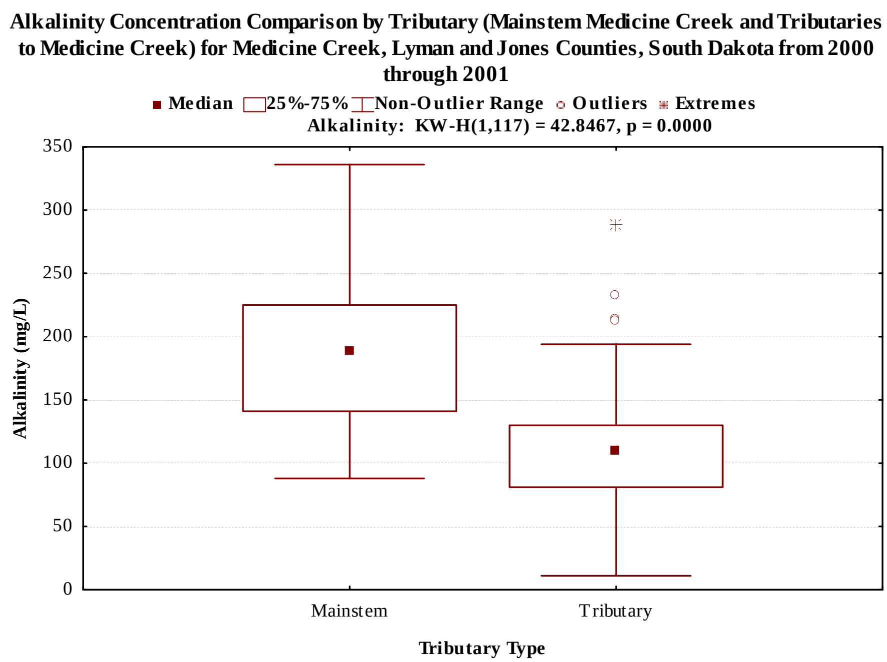


Figure 23. Alkalinity concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total alkalinity loading to Medicine Creek by site was highest at site MCT-13 with 1,522,605 kg/year or 41.2 percent of the total alkalinity loads (Table 21). Alkalinity loads at the outlet site

(MCT-13) of Medicine Creek was highest in April of 2001. Alkalinity loading between sampling sites was statistically similar (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed (34.53 kg/acre) and had 15.1 percent of the hydrologic load (Table 21). Tributary alkalinity loading by season was highest in the spring of 2001 for Medicine Creek sites and Byre Lake (Figure 24).

Stream channel load reduction potentials are segments of the Medicine Creek watershed where load reductions occurred overall and on a per acre basis with a physical or hydrological scenario for the observed load reduction. Five sub-watersheds in Medicine Creek had overall load reductions in alkalinity during the project period MCT-2, MCT-8, MCT-9, MCT-10 and MCT-15. Three sub-watersheds (MCT-8, MCT-10 and MCT-15) were directly downstream of reservoirs (Fate Dam, Brakke Dam and Lake Byre, respectively). Two stream segments (MCT-2 and MCT-9) indicated alkalinity reductions potential. MCT-2 was a highly vegetated segment with reduced flow and MCT-9 was a pooled slack water section of Medicine Creek. Seasonally, alkalinity load reductions in Medicine Creek and Byre Lake occurred in the spring of 2001 (Figure 24).

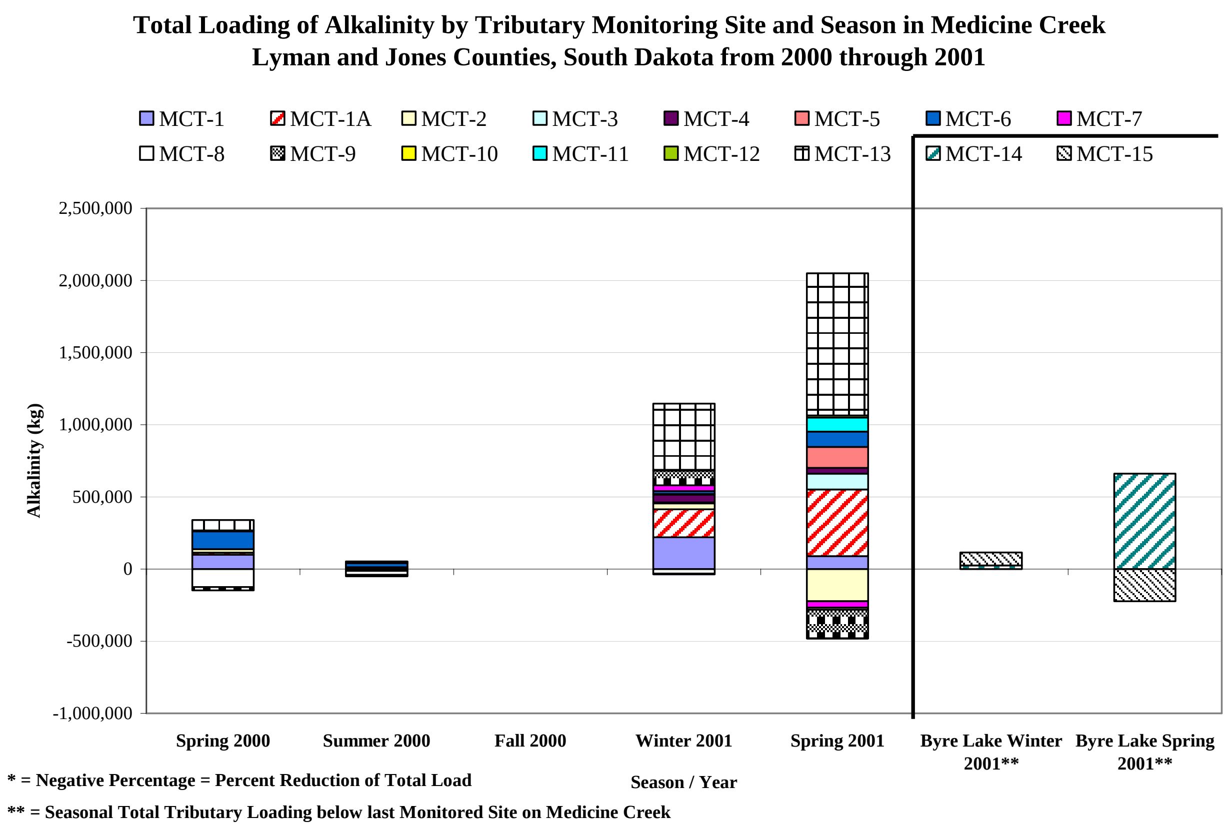


Figure 24. Estimated total alkalinity loads by tributary monitoring site and season in Medicine Creek, Lyman County, South Dakota in 2000 and 2001.

Table 21. Alkalinity loading per year by site for Medicine Creek and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Alkalinity as Ca_2CO_3 Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	422,338	7.60	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	670,294	20.88	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-171,414	-	-7.63	Extremely Vegetated
Stony Butte Creek	**MCT-3**	33,254	6.1%	116,535	3.50	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	95,528	4.19	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	10,249	0.86	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	-131,120	-	-4.20	Slack water, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	149,833	18.79	-	
Nail Creek	**MCT-6**	7,451	8.5%	127,901	17.17	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-44,970	-	-23.28	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	100,018	8.56	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	17,665	5.84	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-12,159	-	-13.26	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	1,522,605	34.53	-	
Gauged Watershed Total		**286,358**	100.0%	3,693,430	12.90	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	687,487	31.26	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-134,585	-	-61.65	Reservoir
Total Monitored Area		310,534	100.0%	4,246,332	13.67		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = **Tributary sites directly affecting Mainstem Medicine Creek**

Blue Highlighted = **Mainstem Medicine Creek**

Solids

Total Solids

Total solids are materials, suspended and/or dissolved, present in natural water and include materials that pass through a filter.

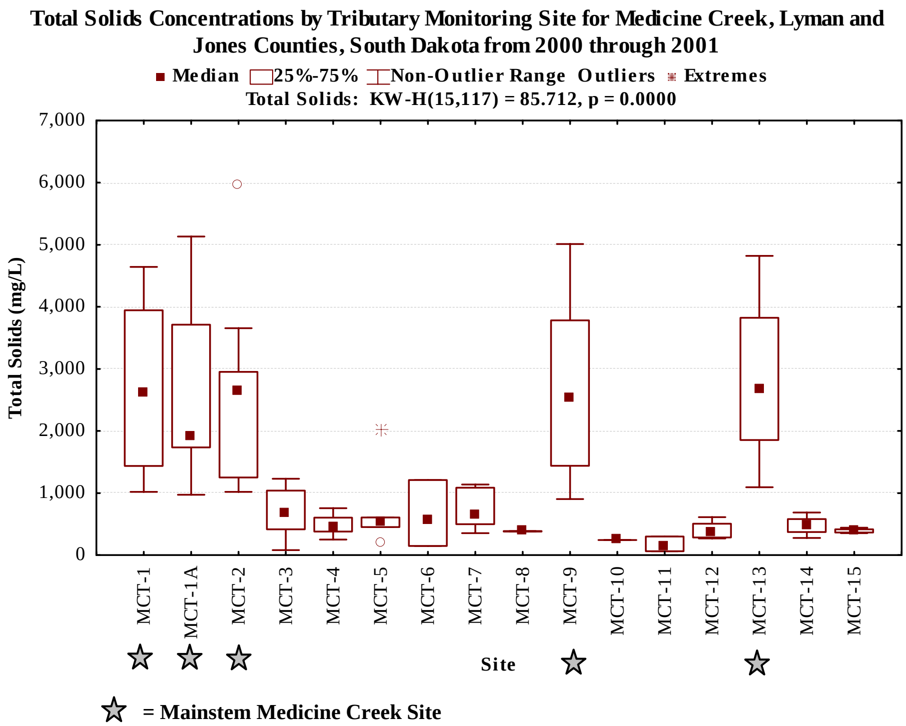


Figure 25. Median, quartile and range of total solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman County, South Dakota from 2000 through 2001.

The median total solids concentrations in Medicine Creek was 1,138.0 mg/L (average 1,679.9 mg/L) with a maximum of 5,950 mg/L collected at MCT-2 on May 22, 2001 and a minimum of 63 mg/L collected at MCT-11 on March 13, 2001 (Figure 25). Total solids concentrations were significantly different between monitoring sites (Figure 25 and Table 4). Most mainstem sampling sites (MCT-1, MCT-1A, MCT-9 and MCT-13) were significantly higher (p=0.000) than MCT-4, MCT-10, MCT-11 and MCT-14) for all dates data was available. A multiple comparison matrix table for total solids is provided in Appendix B, Table B-7 for specific comparisons. Seasonal average concentrations for total solids were highest in the summer at MCT-1A (Table 15).

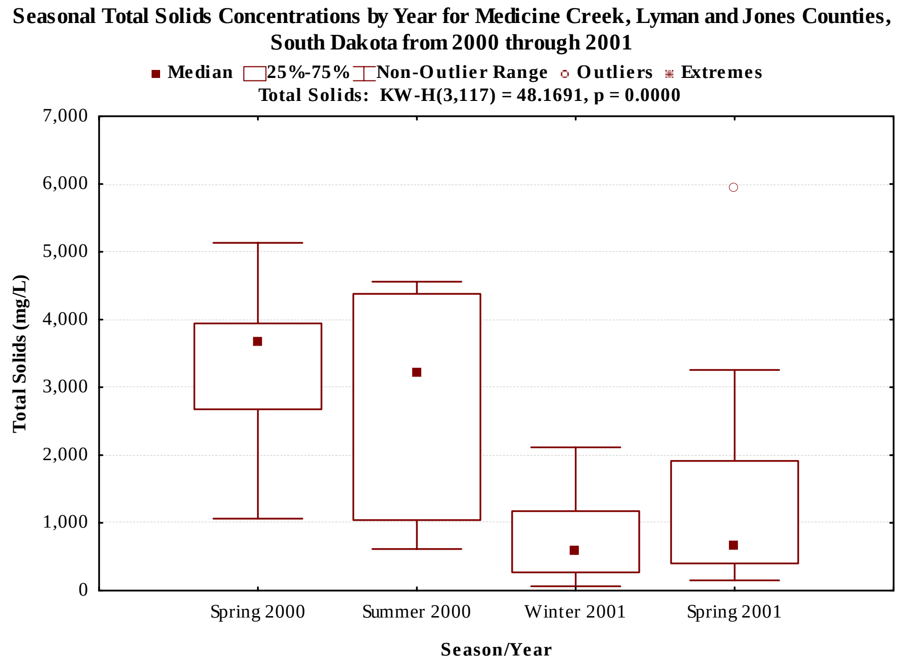


Figure 26. A comparison of total solids concentrations by season in the Medicine Creek watershed, Lyman County, South Dakota from 2000 through 2001.

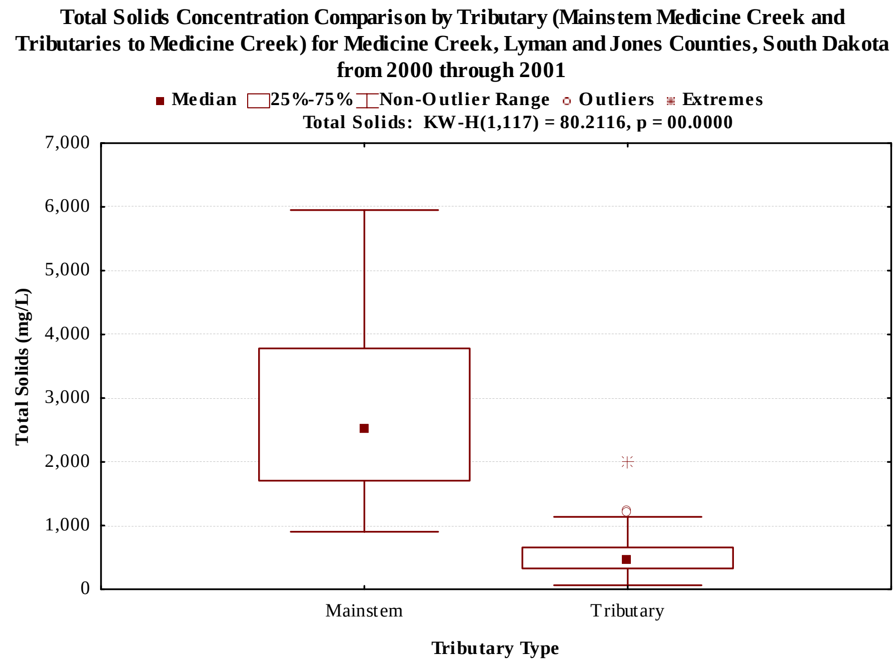


Figure 27. Total solids concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 22. Total solids loading per year by site for Medicine Creek and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Solids Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	8,121,742	146.19	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	7,694,998	239.67	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-7,065,458	-	-314.65	Extremely Vegetated
Stony Butte Creek	**MCT-3**	33,254	6.1%	1,527,835	45.94	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	602,143	26.41	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	-571,215		-47.94	Extremely Vegetated
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	2,133,357	68.38	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	814,196	102	-	
Nail Creek	**MCT-6**	7,451	8.5%	1,091,894	147	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-1,411,532		-730.61	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	273,988	23	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	49,163	16.25	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-101,445		-110.63	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	22,922,260	519.81	-	
Gauged Watershed Total		**286,358**	100.0%	44,591,120	155.72	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	7,601,815	345.65	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-5,271,228		-2,414.67	Reservoir
Total Monitored Area		310,534	100.0%	46,921,707	151.10		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Seasonally, Medicine Creek total solids concentrations collected in the spring and summer of 2000 (lower flows increasing the TDS component of total solids) were significantly higher than concentrations collected in the winter and spring of 2001, with higher flows (Figure 26). Mainstem Medicine Creek total solids concentrations were significantly higher (p=0.000) than concentrations in tributaries to Medicine Creek (Figure 27).

Total solids loading by site was highest at site MCT-13 with 22,922,260 kg/year or 51.4 percent of the total solids load (Table 22). Total solids loading at the outlet site on Medicine Creek (MCT-13) and in the Byre Lake sub-watershed were highest in the spring (April) of 2001. Tributary total solids loading by season was highest in the spring of 2001 for Medicine Creek and Byre Lake sites (Figure 28). Overall total solids loading between sampling sites were significantly different between monitoring sites (Table 4); however, not significant enough (p=0.046) for detecting differences using mean separation procedures (Appendix B, Table B-21). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 (519.81 kg/acre) sub-watershed and contributed 15.1 percent of the total hydrologic load (Table 22).

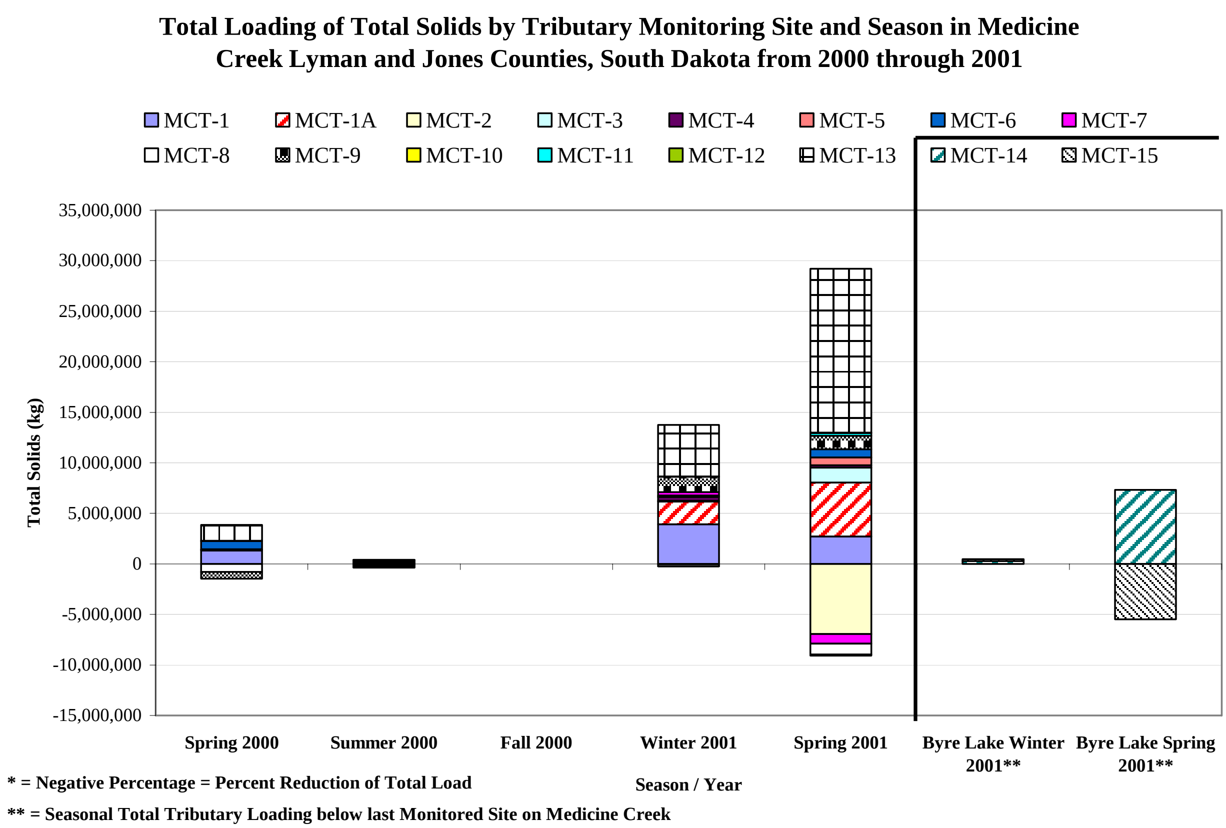


Figure 28. Seasonal total solids loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Five sub-watersheds in Medicine Creek had overall load reductions in total solids during the project period MCT-2, MCT-7, MCT-8, MCT-10 and MCT-15. Higher annual load reductions by sub-watershed occurred at MCT-8 (-730.61 kg/acre), MCT-10 (-110.63 kg/acre) and MCT-15

(-2,414.67 kg/acre) all three monitoring sites were directly downstream of Fate Dam, Brakke Dam and Byre Lake (Table 22). Two stream segments indicated total solids reductions potential. MCT-7 was located on Stony Butte Creek near the confluence of Medicine Creek north of Presho, South Dakota. The observed load reduction potential at MCT-7 was attributed to the segment being highly vegetated creating slack water depositional area with increased evapotranspiration conducive to dissolved solids reduction. MCT-2 was located on mainstem Medicine Creek between Vivian and Presho, South Dakota and like MCT-7, was a highly vegetated depositional area with reduced flow. Seasonally, total solids load reductions in Medicine Creek and Byre Lake occurred in the spring of 2001, with higher seasonal reductions at MCT-2 on Medicine Creek and MCT-15 below Byre Lake (Figure 28).

Total Dissolved Solids

Total dissolved solids concentrations were calculated by subtracting suspended solids concentrations from total solids concentrations. Medicine Creek is listed in The 2004 South Dakota Integrated Report for Surface Water Quality Assessment (305(b) report and 303(d) list combined) as impaired for conductivity and TDS (2004 Integrated Report (page 131)).

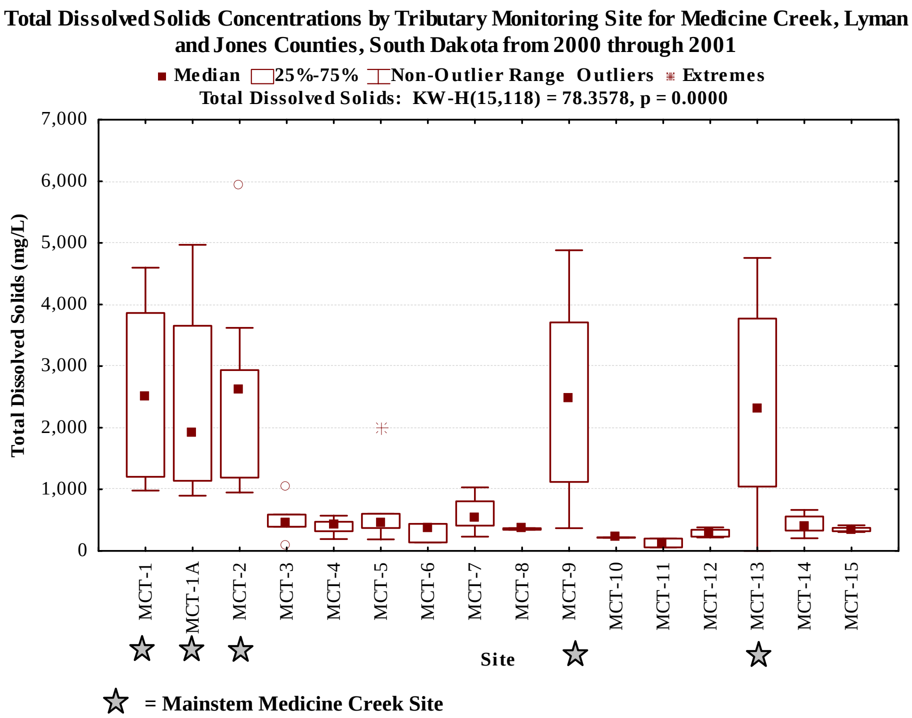


Figure 29. A comparison of total dissolved solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The median total dissolved solids (TDS) concentration was 959.0 mg/L (average 1,543.9 mg/L) with a maximum concentration of 5,931 mg/L recorded at MCT-2 on May 22, 2001 at low flow conditions and a minimum concentration of 56 mg/L at MCT-11 on March 31, 2001 with increased flow/discharge (Figure 29 and Appendix D). Total dissolved solids concentrations between monitoring sites were significantly different (Figure 29 and Table 4). Most mainstem sampling sites (MCT-1, MCT-1A, MCT-2 and MCT-9) were significantly higher (p=0.000) than MCT-4, MCT-11, MCT-12 and MCT-14) for all dates data was available (Appendix B, Table B-8).

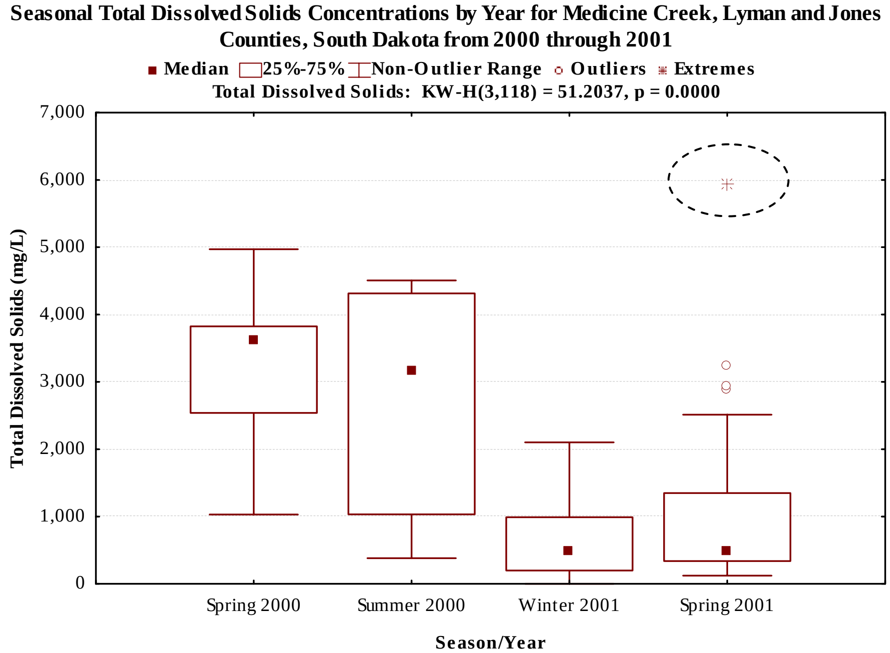


Figure 30. A comparison of total dissolved solids concentrations by season in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site by site comparison of TDS concentrations indicate TDS concentrations were higher in mainstem Medicine Creek (Figure 31). As mentioned previously, TDS and specific conductance values were significantly related in Medicine Creek both overall (Figure 12) and by site comparisons (Figure 13) with a correlation coefficient of r = 0.96. High specific conductance values recorded in Medicine Creek during low flows/discharge were attributed to groundwater dominated flow and Pierre Shale seeps with high concentrations of TDS, nitrate, sodium, sulfate and selenium (Table 20). Thus, violations in assigned beneficial use water quality standards in Medicine Creek for specific conductance and TDS concentrations during low flow conditions should be considered a natural condition in this watershed.

Seasonal average concentrations for total dissolved solids were highest in the summer of 2000 at MCT-1A during groundwater dominated low flow conditions (Table 15). The highest TDS concentration (5,931 mg/L) was recorded in late May of 2001 at MCT-2 during low flow/discharge conditions (Figure 29 and dashed oval in Figure 30). By late May 2001, most monitored tributaries to mainstem Medicine Creek stopped flowing and monitored sites on Medicine Creek ranged from no flow in the upper end of the watershed (MCT-1 and MCT-1A) to low flow conditions at MCT-2, MCT-9 and MCT-13.

Table 23. Total dissolved solids loading per year by site for Medicine Creek and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Dissolved Solids Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	5,895,298	106.11	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	5,233,132	163.00	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-720,792	-	-32	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	615,674	18.51	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	354,146	15.53	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	103,073	8.65	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	-6,253,943	-	-200.45	Slack water, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	737,189	92	-	
Nail Creek	**MCT-6**	7,451	8.5%	8,742	1	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-323,873	-	-167.64	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	202,450	17	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	38,045	12.57	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-42,546	-	-46.40	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	7,694,943	174.50	-	
Gauged Watershed Total		**286,358**	100.0%	19,511,860	68.14	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	2,804,055	127.50	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-893,183		-409.15	Reservoir
Total Monitored Area		310,534	100.0%	21,422,732	68.99		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

TDS concentrations in tributaries to Medicine Creek (MCT-3, MCT-4, MCT-5, MCT-6, MCT-7, MCT-8, MCT-10, MCT-11, MCT-12, MCT-14 and MCT-15) were below assigned beneficial use water quality standards for TDS. Mainstem Medicine Creek TDS concentrations were significantly higher (p=0.0000) than concentrations in tributaries to Medicine Creek (Figure 31).

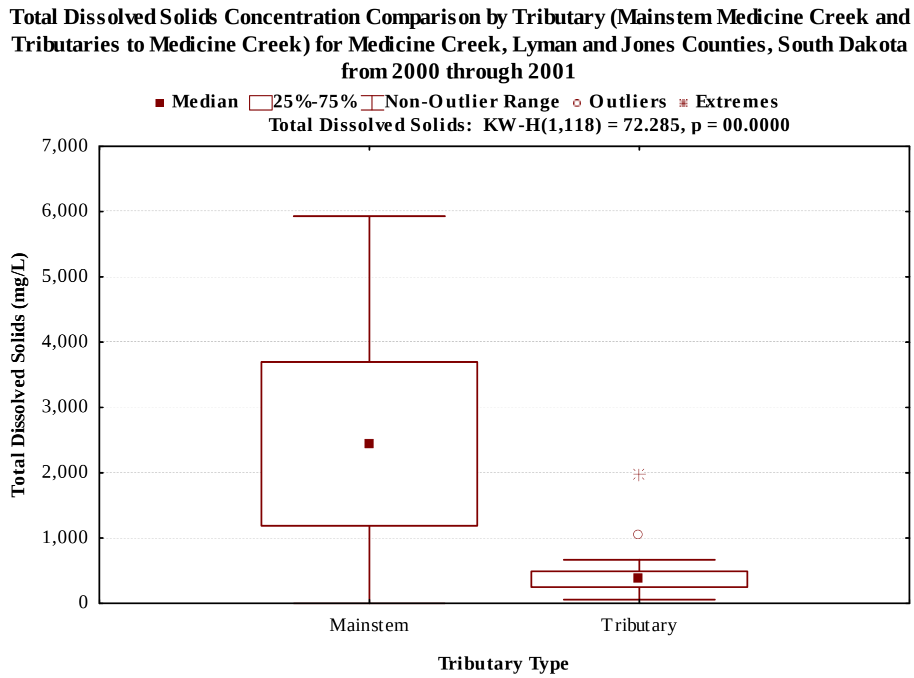


Figure 31. Total dissolved solids concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total dissolved solids loading by site was highest at site MCT-13 (7,694,943 kg) comprising 39.4 percent of the total dissolved solids load (Table 23). TDS loading in the Byre Lake sub-watershed were also highest in the spring of 2001. Tributary total dissolved solids loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake sites (Figure 32). Overall total solids loading between sampling sites were statistically similar (p=0.063, Appendix B, Table B-22). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed (174.50 kg/acre) and contributed 15.1 percent of the total hydrologic load (Table 23).

Five sub-watersheds in Medicine Creek had overall load reductions in total solids during the project period, MCT-2, MCT-8, MCT-9, MCT-10 and MCT-15. Three of the five annual load reductions by sub-watershed occurred at MCT-8 (-176.64 kg/acre), MCT-10 (-46.40 kg/acre) and MCT-15 (-409.15 kg/acre) all three monitoring sites were directly downstream of Fate Dam, Brakke Dam and Byre Lake, respectively (Table 23). Load reduction at MCT-9, mainstem monitoring site located approximately 4.5 km (2.8 miles) east of Presho, South Dakota may be influenced by hydrologic conditions upstream of MCT-9 at Presho, South Dakota. When Medicine Creek reaches Presho, water slows and pools, especially during low flows, resulting in TDS reductions similar to reservoirs located in the watershed (Fate Dam, Brakke Dam and Byre

Lake). TDS load reductions at MCT-2 located on mainstem Medicine Creek between Vivian and Presho, South Dakota were attributed to the segment being highly vegetated creating a slack water depositional area conducive to general load reduction. Seasonally, TDS load reductions in Medicine Creek were higher by monitoring site at MCT-9 in the winter of 2001 and higher in the spring of 2001 in the Byre Lake MCT-15 (Figure 32).

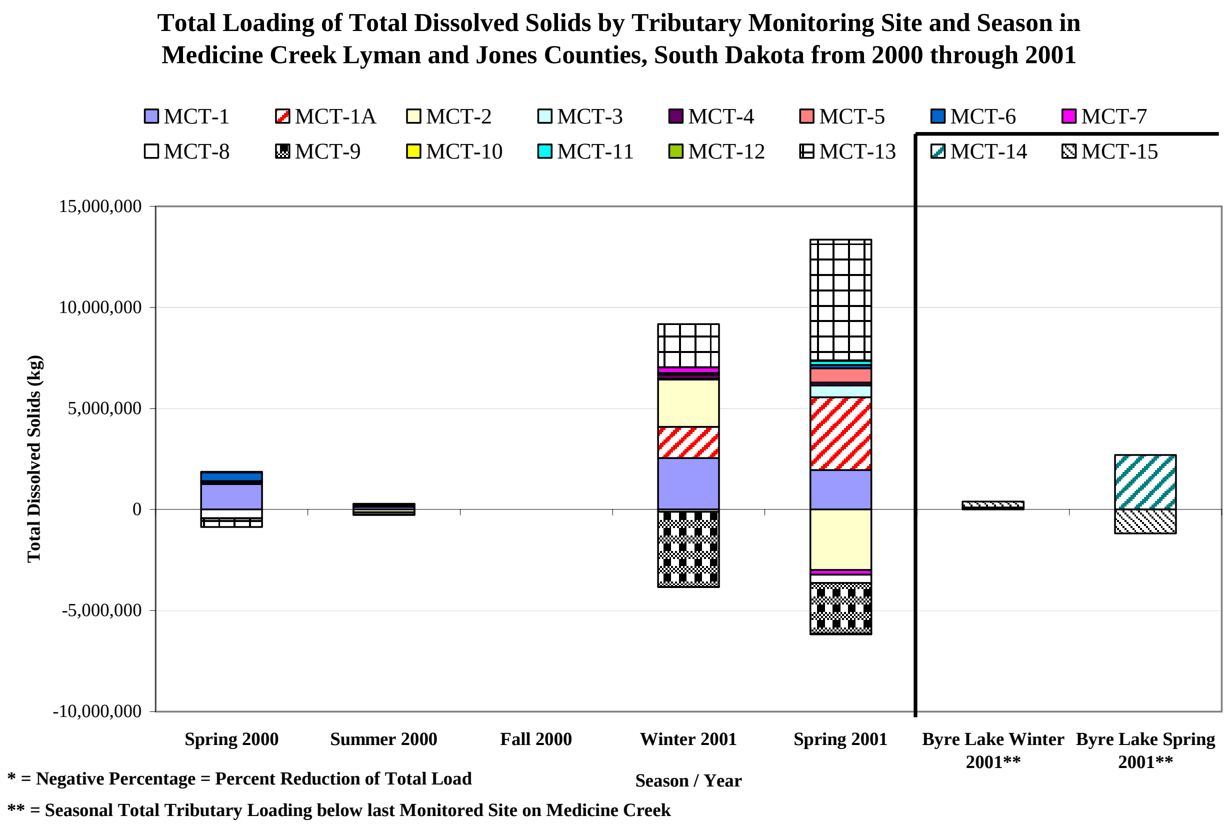


Figure 32. Seasonal total dissolved solids loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

In the specific conductance portion of this report (page 45), Medicine Creek seep samples were compared to groundwater well and seep samples collected in the Freeman Dam watershed, also in the Pierre Shale formation (Table 20). Freeman Dam well and seep samples had very high conductivity values, TDS, nitrate, sulfate, sodium and selenium concentrations. Groundwater seeps with high TDS, nitrate concentrations and specific conductance values were linked to high TDS, nitrate concentrations and specific conductance values in Freeman Dam by way of surface and groundwater runoff concentrating in Freeman Dam. Thus, under certain conditions and locations, natural alkali/saline seeps in Pierre Shale formations can cause high concentrations of TDS, nitrates, sulfate, sodium and selenium concentrations increasing specific conductance values in receiving waters and should be considered a natural condition.

Medicine Creek seep samples show similar high concentrations of TDS, nitrates, sulfate, sodium and selenium and specific conductance values as did Freeman Dam (Table 20). Data from Freeman Dam and Medicine Creek indicate that under certain conditions, high TDS, nitrate sulfate, sodium and selenium concentrations resulting in high specific conductance values occur and may be common throughout the Pierre Shale formation. Violations in assigned beneficial use based water quality standards in Medicine Creek for TDS and by default specific conductance values occur during low flow conditions because geological conditions create high TDS concentrations in receiving waters in mainstem Medicine Creek.

Three constituents of TDS, Sodium (Na^{+}), Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) were used to calculate SAR ratios in two seep samples collected in the Medicine Creek watershed. These were calculated to estimate the potential impact the seeps (contributing high TDS concentrations and specific conductance values) may have on their respective tributaries. Generally, the SAR standard ($\leq$ 10 milliequivalents per liter (me/L)) applies to all streams of the State with beneficial use based water quality standard for 10-irrigation waters (exception: Belle Fourche River $\leq$ 6 me/L). SAR results for seep samples exceeded the water quality standard (Anderson 1, 36.0 me/L and Urban 1, 107.6 me/L) and suggest that seeps originating in the Pierre Shale formation have high SAR and may impact both tributaries and mainstem Medicine Creek. As mentioned in the specific conductance section of this report, routine assessment water quality samples collected during the project did not include sampling for Sodium (Na^{+}), Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) so SAR exceedance in the Medicine Creek watershed could not be ascertained.

The assigned beneficial use classifications for Medicine Creek (stream segment mainstem Medicine Creek from the Lower Brule Reservation boundary to Highway 83 overpass) is warmwater marginal fish life propagation water, limited-contact recreation water, Fish and wildlife propagation, recreation, and stock watering water and irrigation water. Data indicate that the beneficial use based water quality standard for TDS has been exceeded (Table 9). Due to natural conditions in the Pierre Shale, most high TDS violations (< 4,375 mg/L) occur during groundwater and seep dominated low flow/discharge conditions. Based on naturally occurring TDS concentrations in seep and groundwater, Medicine Creek can not meet current water quality standards, especially at low flow conditions. Current and long-term data suggest that in the Medicine Creek watershed, high TDS values occur throughout mainstem Medicine Creek, especially during low flows due to natural (geological) conditions.

Total Suspended Solids

Total suspended solids (TSS) are the materials that do not pass through a filter, e.g. sediment and algae. Medicine Creek is not listed in the 2004 South Dakota Integrated Report for Surface Water Quality Assessment as impaired for TSS (2004 Integrated Report (page 131)); however, during the assessment, violations in the TSS standards for warmwater marginal fish life propagation water (Table 7, 263 mg/L) were recorded through out mainstem Medicine Creek (11.3 percent violation rate, Table 10). Mainstem TSS assessment data (62 samples) were incorporated with monthly WQM data (58 samples) to determine the overall TSS violation percentage. Based on Table 10, 10.0 percent of all TSS samples collected from mainstem Medicine Creek violated assigned beneficial use water quality standards. One possible reason 11.3 percent of assessment TSS samples violated water quality standards were that a number of these samples were collected during runoff events resulting in event based TSS concentrations.

Whereas monthly WQM samples for Medicine Creek were collected on the same date every month that may or may not be event based.

The median total suspended solids (TSS) concentration during the project was 50.5 mg/L (average 132.9 mg/L) with a maximum of 1,760.0 mg/L recorded at MCT-9 on April 25 2001 at increasing flow/discharge and a minimum concentration of 2 mg/L at MCT-4 collected on two dates May 13 2001 and May 22 2001 during low flow/discharge. Site by site comparison of TSS concentrations indicate that median TSS concentrations in Medicine Creek were below 200 mg/L (Figure 33). TSS concentrations were statistically similar between monitoring sites (Figure 33 and Table 4). Figure 33 shows most Medicine Creek monitoring sites MCT-1, MCT-1A, MCT-9 and MCT-13 exceeded the 263 mg/L at least once. Specific violations in TSS standards by WQM site and mainstem assessment monitoring sites are provided in Table 10.

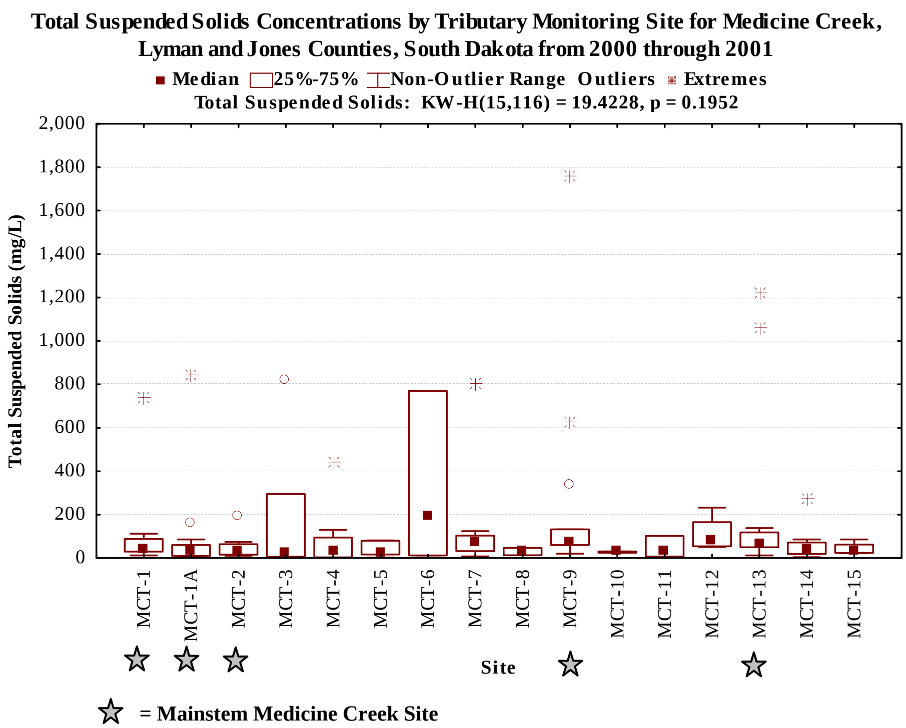


Figure 33. Total suspended solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Seasonal TSS concentrations were significantly different between seasons; however, not significant enough (p=0.0462) for detecting differences using mean separation procedures (Figure 34). Mainstem Medicine Creek and tributaries to Medicine Creek TSS concentrations were statistically similar (p=0.134) during the study (Figure 35).

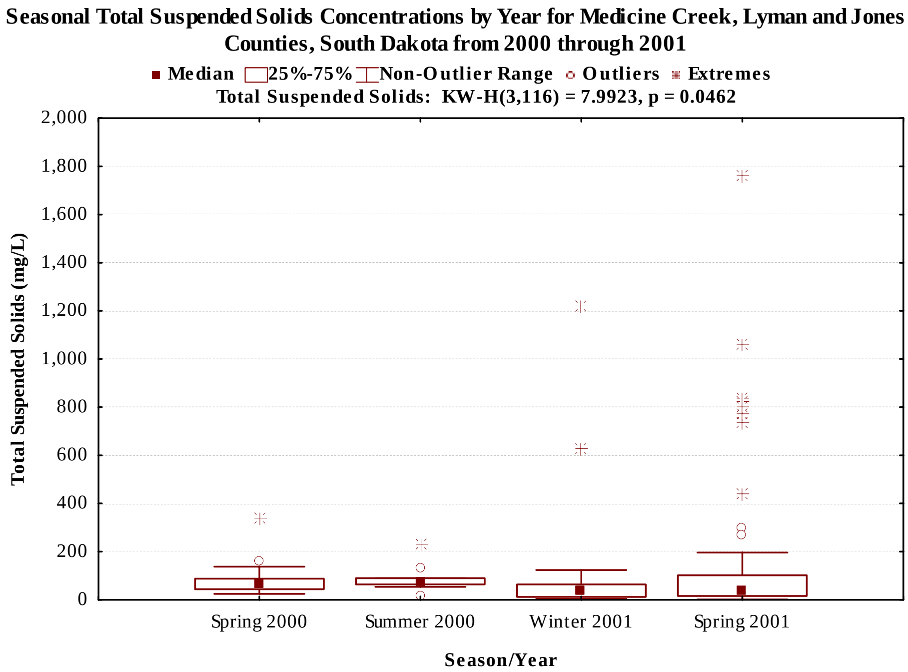


Figure 34. Total suspended solids concentrations by season in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

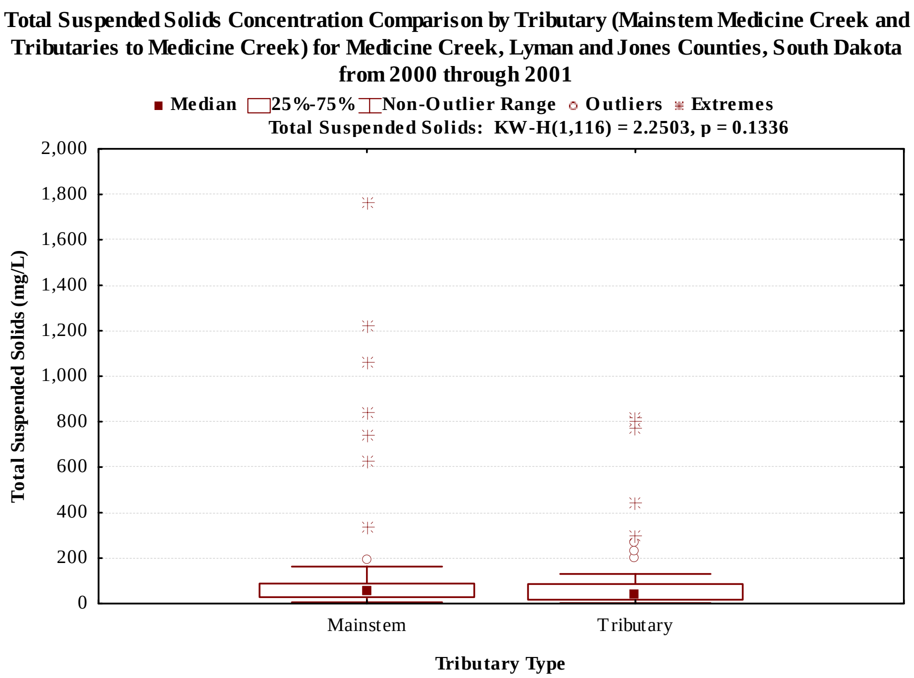


Figure 35. Total suspended solids concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 24. Total suspended solids loading per year by site for Medicine Creek and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Suspended Solids Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	2,351,850	42.33	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	2,914,094	90.76	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-6,152,826	-	-274.01	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	1,024,775	30.82	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	247,996	10.88	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	-786,901	-	-66.05	Extremely Vegetated Reach
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	7,238,277	232.00	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	541,273	68	-	
Nail Creek	**MCT-6**	7,451	8.5%	154,620	21	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-1,095,633	-	-567.10	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	71,538	6	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	11,118	3.67	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-59,718	-	-65.12	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	15,310,140	347.19	-	
Gauged Watershed Total		**286,358**	100.0%	25,225,970	88.09	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	4,797,761	218.15	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-4,378,045		-2,005.52	Reservoir
Total Monitored Area		310,534	100.0%	25,645,686	82.59		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Medicine Creek between Presho and Kennebec, South Dakota (west of MCT-9 through MCT-13) is incised with little in-stream woody debris or vegetation. In the incised sections of Medicine Creek, the stream has little access to its flood plain to dissipate hydrologic energy and deposit sediment during high flow (high energy) events. With little access to the floodplain during high flow, the hydrologic energy is restricted to the stream channel (stream bed and banks) increasing the potential for scouring and further down cutting of the channel bottom, undercutting stream banks causing bank failure which deposits more sediment in the stream and increases general channel widening.

These conditions increase TSS concentrations and loading, especially during high flow events in Medicine Creek. The above scenario was observed in this sub-watershed (MCT-13) with the highest TSS loading by sub-watershed 22,068,706 kg in Medicine Creek (Table 24).

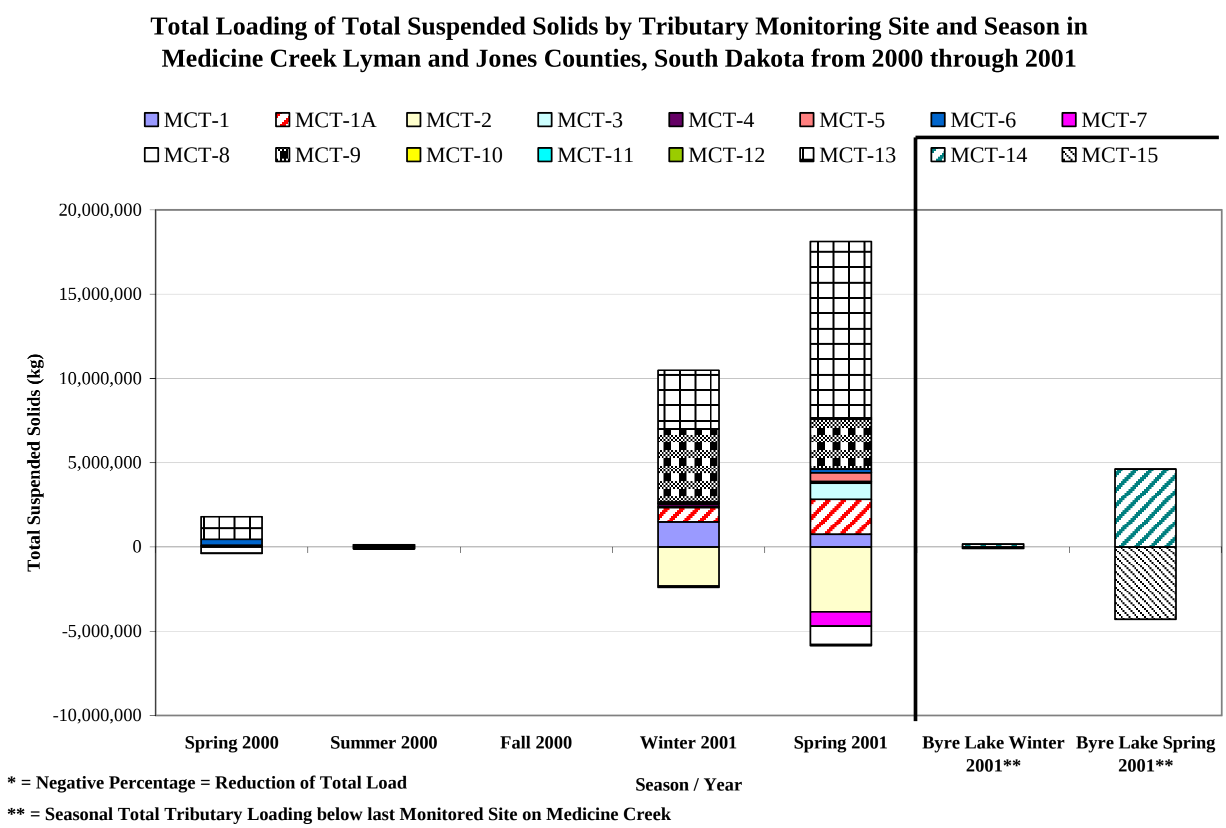


Figure 36. Seasonal total suspended solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Suspended solids loading by site was highest at site MCT-13 comprising 60.7 percent of the total suspended solids load (Table 24). Tributary total suspended solids loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake watersheds (Figure 36). Overall total suspended solids loading between sampling sites were significantly different between monitoring sites (Table 4); however, not significant enough (p=0.039) for detecting differences using mean separation procedures (Appendix B, Table B-23). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed (347.19 kg/acre) and contributed 15.1 percent of the total hydrologic load (Table 24).

Five sub-watersheds in Medicine Creek had overall load reductions in TSS during the project period, MCT-2, MCT-7, MCT-8, MCT-10 and MCT-15. Three of the five annual load reductions by sub-watershed occurred at Fate Dam (MCT-8, -567.10 kg/acre), Brakke Dam, (MCT-10 -65.12 kg/acre) and Byre Lake (MCT-15, -2,005.52 kg/acre) all three monitoring sites were directly downstream of the their respective reservoirs (Table 24). Load reduction potential recorded at MCT-7, north of Presho, was attributed to the segment being highly vegetated creating slack water depositional area conducive to solids reduction. Mainstem monitoring site MCT-2 was located on between Vivian and Presho like MCT-7, was a highly vegetated depositional area with reduced flow. Seasonally, total suspended solids load reductions were higher in the spring of 2001 at MCT-2 in Medicine Creek and in Byre Lake MCT-15 (Figure 36).

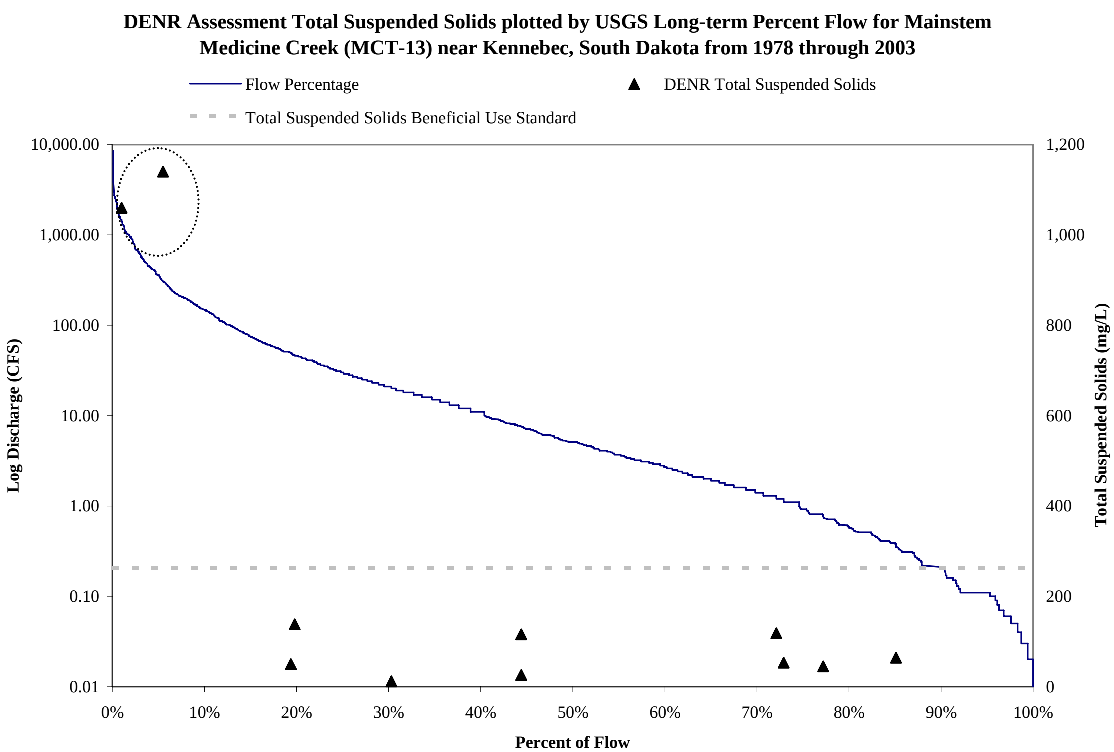


Figure 37. Total suspended solids concentration relationship to flow for Medicine Creek (MCT-13), Lyman and Jones Counties, South Dakota from 2000 through 2001.

Figure 37 indicates all violations in assigned beneficial use standards for TSS at MCT- 13 occurred during high flow/runoff events (dashed oval) and most TSS violations collected from other monitoring sites along the segment (MCT-1, MCT-1A, MCT-2 and MCT-9) also occurred during high flows (Table 10). All TSS exceedances occurred in the top 5 percent (> 270 cfs) of all flows/discharge (Figure 37). Best Management Practices (BMPs) reducing TSS concentrations during runoff events should be implemented. AnnAGNPS modeling identified improvements in buffers, tillage practices and grazing management in pastures throughout Medicine Creek should reduce sediment loading to Medicine Creek (Appendix C).

Although not listed in the 2004 South Dakota Integrated Report for Surface Water Quality Assessment as impaired for TSS, data suggest that 10.0 percent of all TSS samples collected in Medicine Creek violated assigned surface water quality standards for TSS (Table 10). TMDL listing criteria for South Dakota waters are if more than 10 percent of the samples (20 sample minimum) exceed the water quality standard the site is impaired and requires a TMDL (SD DENR, 2004). TSS violations in Medicine Creek exceeded the TMDL listing criteria; because of this, Medicine Creek would be listed in the 2006 Integrated Repot as non-support for TSS standards based on the warmwater marginal fish life propagation water beneficial use listing. Therefore, a TMDL was developed for TSS to reduce TSS concentrations and improve water quality in Medicine Creek. Implementing modeled BMPs in critical areas of the Medicine Creek watershed will reduce TSS concentrations towards meeting the TMDL goal for total suspended solids. Flux modeled priority sub-watersheds for TSS in mainstem Medicine Creek based on export coefficients are presented in Table 25.

Table 25. Medicine Creek watershed mitigation priority sub-watersheds for total suspended solids based on 2000 – 2001 watershed assessment modeling.

Priority Rank	Mainstem Sub-watershed	TSS Export Coefficient (kg/acre)	Total load by site (kg)
1	MCT-13	347.19	15,310,140
2	MCT-9	232.00	7,238,277
3	MCT-1A	90.76	2,914,094
4	MCT-1	42.33	2,351,850

TMDL development for TSS consisted of calculating the WLA (Waste Load Allocation) for all point sources that potentially discharge to mainstem Medicine Creek. The WLA (Waste Load Allocation) was calculated using the TSS standard for warmwater marginal fish life propagation water (263 mg/L) and the potential discharge from each facility provided by SD DENR SWQP. WLA was calculated using conservative discharge calculations and accounted for increased rainfall events and future municipal growth. Load reductions from the watershed were modeled/estimated using the AnnAGNPS model to estimate an attainable LA (Load Allocation) for TSS. The MOS (Margin-Of-Safety) was considered implicit in that all load reductions were calculated using conservative estimates.

Attainable TSS load reduction percentages estimated by AnnAGNPS were modeled using the FLUX program to calculate the appropriate TSS LA for Medicine Creek. To calculate the reduction in TSS load, the overall TSS violation percentage (10.0 percent) was used to reduce 10 percent of the assessment concentrations at MCT-13 (1 sample out of 10 total samples collected) and re-run the FLUX model using the adjusted concentration data (adjusting one TSS sample violation to the water quality standard (1,220 mg/L to 263 mg/L) with the original 2000 through 2001 hydrologic load. Because most violations occurred during high flow events, the realized modeled reduction percentage (20.1 percent) was greater than the initial modeled reduction (10 percent).

The TSS TMDL for Medicine Creek is to reduce the current annual load allocation to 20,164,594 kg/yr or approximately 20.1 percent producing a TSS TMDL of 20,172,490 kg/year (an approximate overall reduction of 20 percent) with an implicit MOS (Table 52). This TMDL 20,172,490 kg/year translates into a 10 percent reduction in the violation rate for TSS (263 mg/L for any one grab sample) and should meet the TSS standard for warmwater marginal fish life propagation water. All TSS load reductions needed to meet the TMDL come exclusively from the load allocation (LA) because no realistic reduction can be expected from the waste load allocation (WLA).

Volatile Total Suspended Solids

Volatile total suspended solids (VTSS) are that portion of suspended solids that are organic (organic matter that burns in a 500° C muffle furnace).

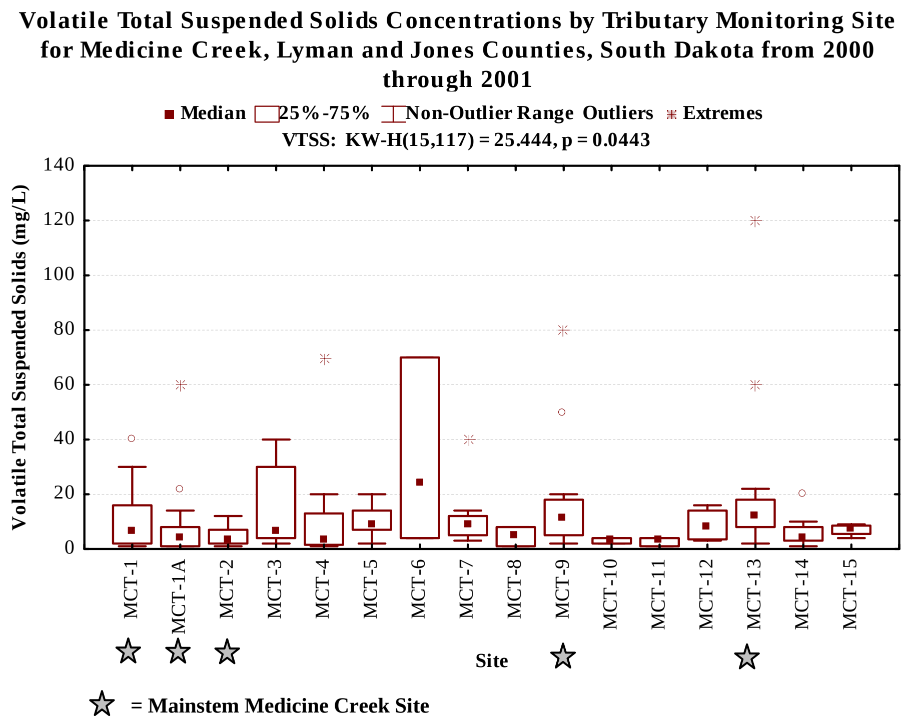


Figure 38. Volatile total suspended solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The median VTSS concentration during the Medicine Creek project was 6.0 mg/L (average 12.4 mg/L) with a maximum concentration of 120.0 mg/L recorded at MCT-13 on March 19 2001 during an increasing flow event. Minimum VTSS concentrations of 1.0 mg/L were collected from MCT-1, MCT-1A and MCT-2 on the mainstem of Medicine Creek and from MCT-4, MCT-8, MCT-11 and MCT-14 on tributaries to Medicine Creek in 2001 (Appendix D). Site by site comparison of TSS concentrations indicate that median VTSS concentrations in Medicine Creek were generally below 20 mg/L, except at MCT-6 (Figure 38). VTSS concentrations were statistically different between monitoring sites (Figure 38 and Table 4); however, not significant enough (p=0.0443) for detecting differences using mean separation procedures (Appendix B,

Table B-10). The organic percentage (VTSS) of total suspended solids (TSS) in Medicine Creek ranged from 0.5 percent to 80.0 percent during the project (Appendix D).

Seasonally, VTSS concentrations were significantly different between sampling seasons (p=0.0101) with concentrations in the summer of 2000 being significantly higher than winter and spring concentrations in 2001 (Figure 39). Mainstem Medicine Creek VTSS concentrations were similar than concentrations in tributaries to Medicine Creek (Figure 40).

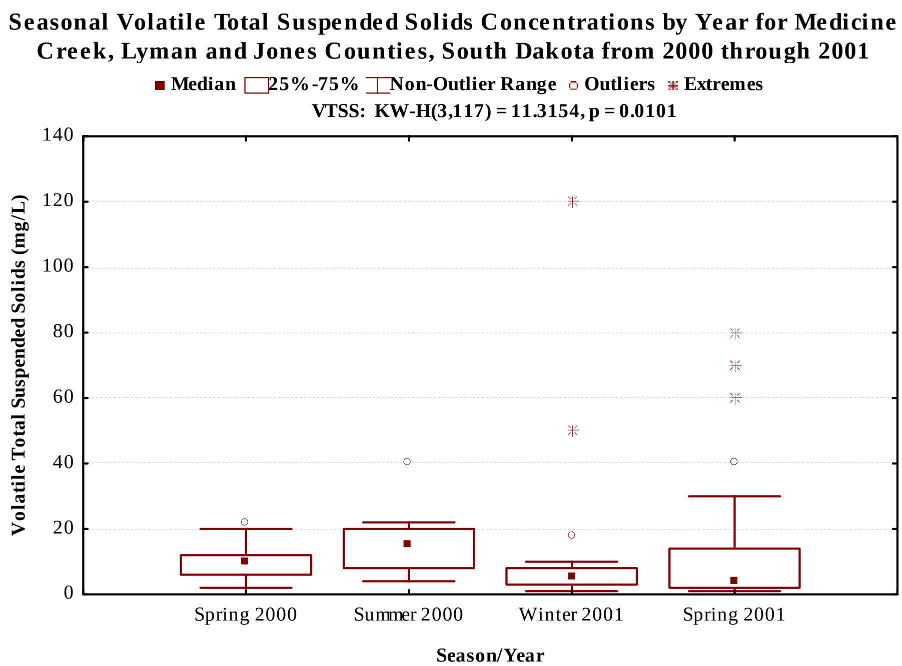


Figure 39. Seasonal Volatile total suspended solids concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

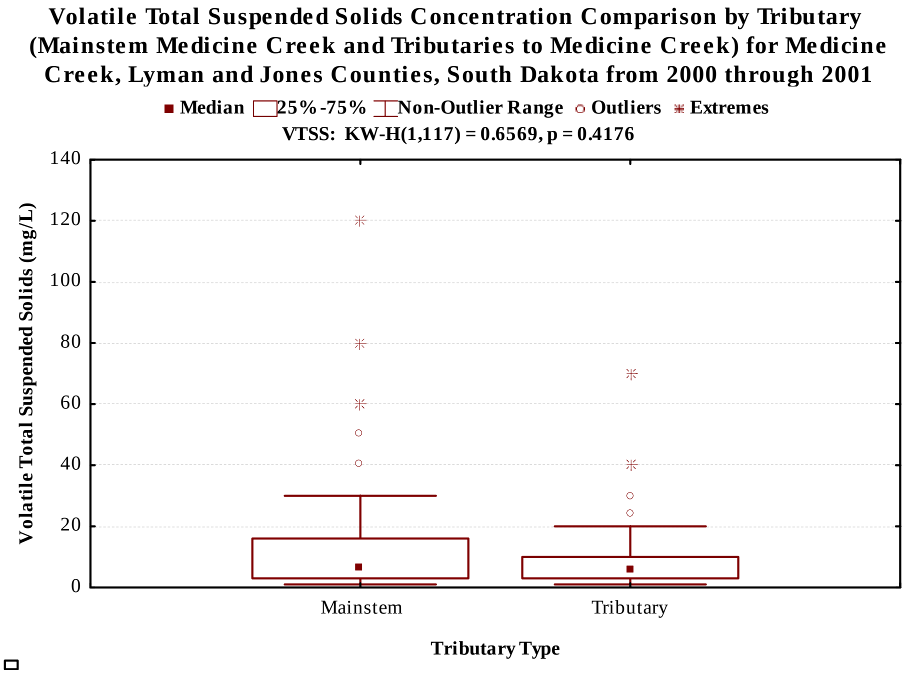


Figure 40. Volatile total suspended solids concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 26. Volatile total suspended solids loading per year by site for Medicine Creek and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Volatile Total Suspended Solids Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	-11,113	-	-0.20	Channel less vegetated than MCT-1A
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	209,690	6.53	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-283,973	-	-12.65	Vegetated Depositional Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	38,452	1.16	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	38,046	1.67	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	-40,918	-	-3.43	Vegetated Depositional Reach
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	595,020	19.07	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	27,412	3.44	-	
Nail Creek	**MCT-6**	7,451	8.5%	75,534	10.14	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-106,841	-	-55.30	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	4,546	0.39	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	1,172	0.39	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-3,961	-	-4.32	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	833,563	18.90	-	
Gauged Watershed Total		**286,358**	100.0%	1,613,731	5.64	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	436,142	19.83	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-389,214		-178.29	Reservoir
Total Monitored Area		310,534	100.0%	1,660,659	5.35		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

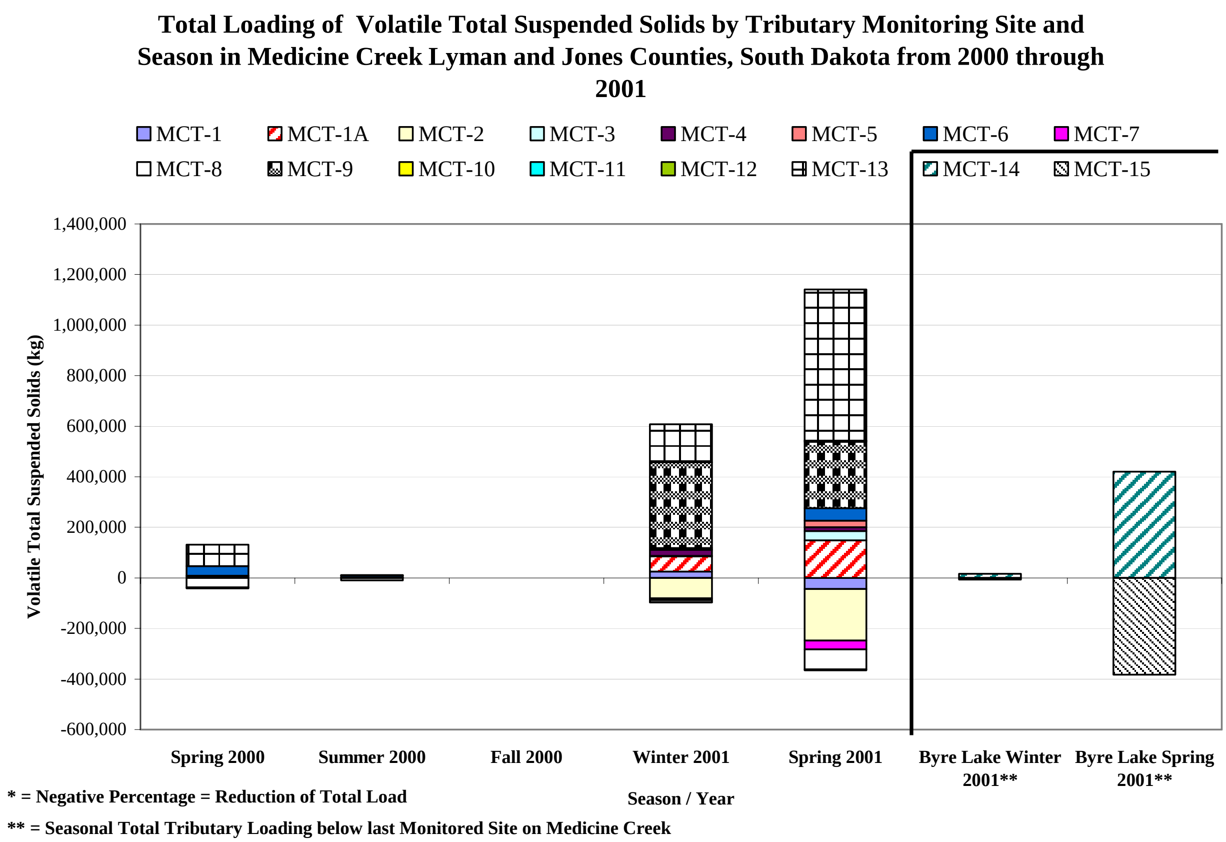


Figure 41. Seasonal Volatile total suspended solids loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

VTSS loading by site was highest at site MCT-9 comprising 36.9 percent of the VTSS load and 0.2 percent of the hydrologic load (Table 26). Tributary VTSS loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake watersheds (Figure 41). Overall volatile total suspended solids loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) in mainstem Medicine Creek were highest in the MCT-9 sub-watershed (19.07 kg/acre) and were highest at MCT-14 in the Byre Lake sub-watershed at 19.83 kg/acre (Table 26).

Six sub-watersheds in Medicine Creek had overall load reductions in VTSS during the project period, MCT-1, MCT-2, MCT-7, MCT-8, MCT-10 and MCT-15. Like most parameters, three of the six annual load reductions by sub-watershed occurred at Fate Dam (MCT-8, -55.30 kg/acre), Brakke Dam, (MCT-10 -4.32 kg/acre) and Byre Lake (MCT-15, -178.29 kg/acre) with all three monitoring sites located directly downstream of the their respective reservoirs (Table 26). Load reduction potentials recorded at MCT-2 between Vivian and Presho and MCT-7, Stony Butte Creek north of Presho, were attributed to the segments being highly vegetated depositional areas conducive to increased organic matter and detritus. Load reduction at mainstem monitoring site MCT-1 located near Vivian was attributed to the stream channel in this segment having reduced vegetation in comparison to MCT-1A. Seasonally, total suspended solids load reductions were higher in the spring of 2001 at MCT-2 in Medicine Creek and in Byre Lake MCT-15 (Figure 41).

Ammonia

Ammonia is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the Medicine Creek watershed may come from animal feeding areas, decaying organic matter or bacterial conversion of other nitrogen compounds.

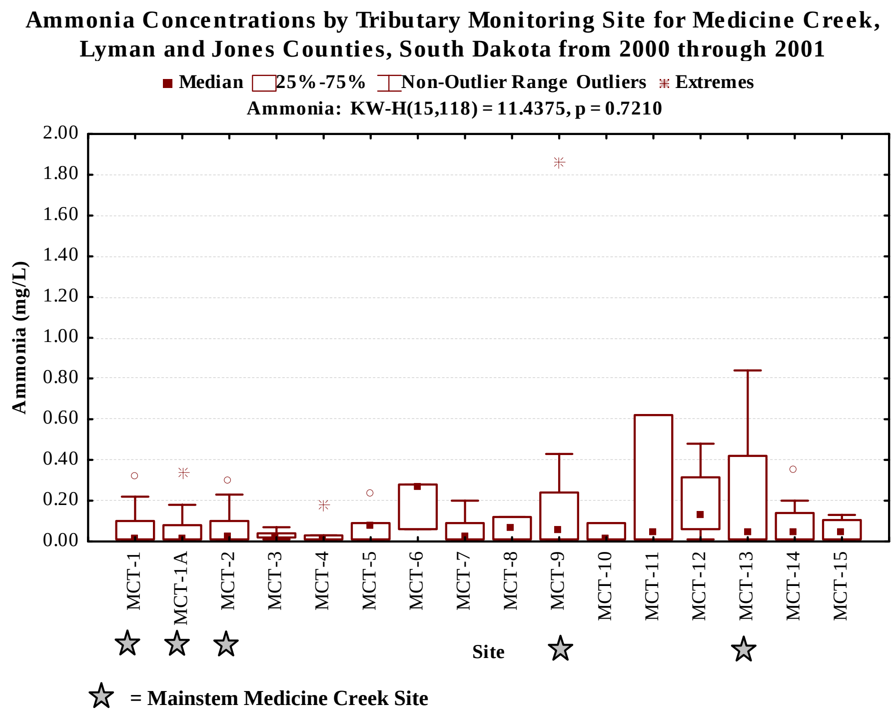


Figure 42. Ammonia concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Minimum ammonia concentrations (0.01 mg/L, ½ the detection limit) were collected on a variety of dates from most sites in Medicine Creek except MCT-6 (Appendix D). The median ammonia concentration in Medicine Creek project was 0.02 mg/L (average 0.11 mg/L) with a maximum concentration of 1.86 mg/L recorded at MCT-9 on 3/13/01 during an increasing flow event (Figure 42). Site by site comparison of ammonia concentrations indicate that median ammonia concentrations in Medicine Creek were generally below 0.20 mg/L, except at MCT-6 on Nail Creek above Fate Dam (Figure 42), with ammonia concentrations statistically similar between monitoring sites (Figure 42 and Table 4).

Ammonia concentrations were significantly different between sampling seasons (p=0.0000) with concentrations in the winter of 2001 being significantly higher than the spring and summer of 2000 and the spring of 2001 (Figure 43). Mainstem Medicine Creek ammonia concentrations were statistically similar (p=0.6395) to concentrations in tributaries to Medicine Creek (Figure 44 and Appendix B, Table B-11).

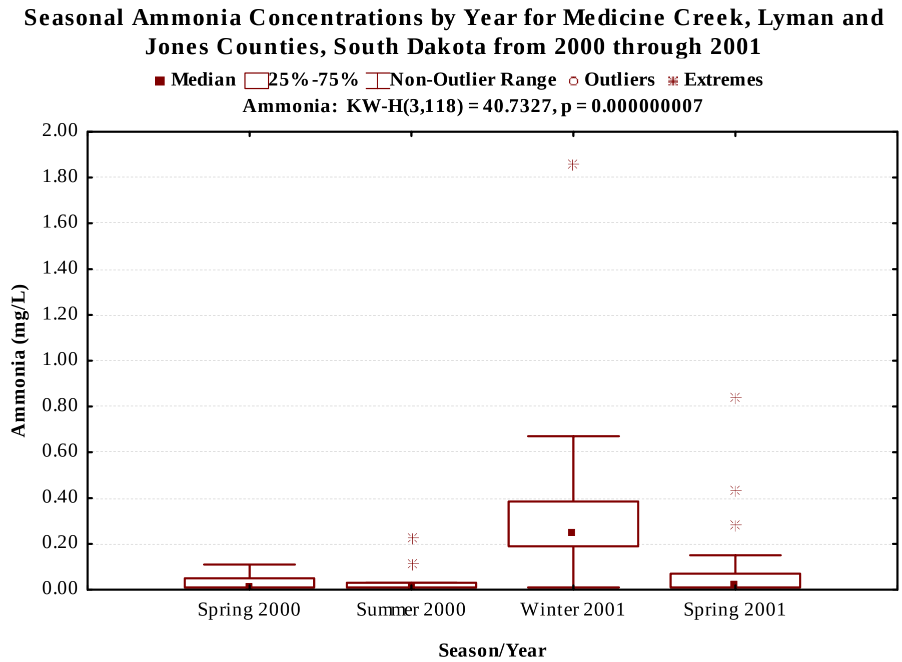


Figure 43. Seasonal ammonia concentrations by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

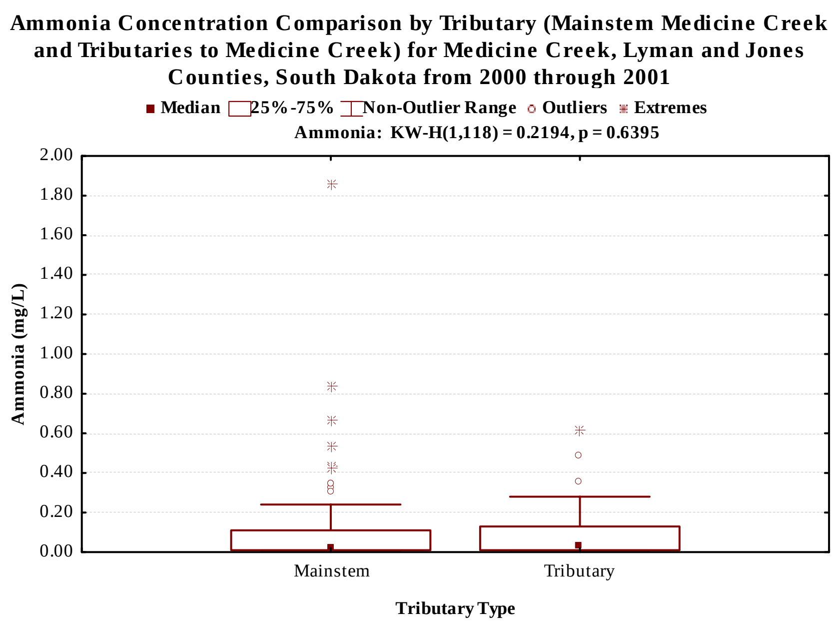


Figure 44. Ammonia concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 27. Ammonia loading per year by site for the Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Ammonia Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	434	0.01	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	598	0.02	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-171	-	-0.01	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	94	0.00	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	130	0.01	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	330	0.03	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	4,815	0.15	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	149	0	-	
Nail Creek	**MCT-6**	7,451	8.5%	130	0	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-339	-	-0.18	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	100	0	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	19	0.01	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-36	-	-0.04	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	10,804	0.25	-	
Gauged Watershed Total		**286,358**	100.0%	17,803	0.06	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	806	0.04	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-203		-0.09	Reservoir
Total Monitored Area		310,534	100.0%	18,406	0.06		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Ammonia loading by site was highest at site MCT-13 (10,804 kg/yr) comprising 60.7 percent of the total ammonia load in Medicine Creek and 15.1 percent of the hydrologic load (Table 27). Tributary ammonia loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake watersheds (Figure 45). Overall total suspended solids loading between sampling sites was not significantly different (Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed (0.25 kg/acre) followed by MCT-9 at 0.15 kg/acre (Table 27).

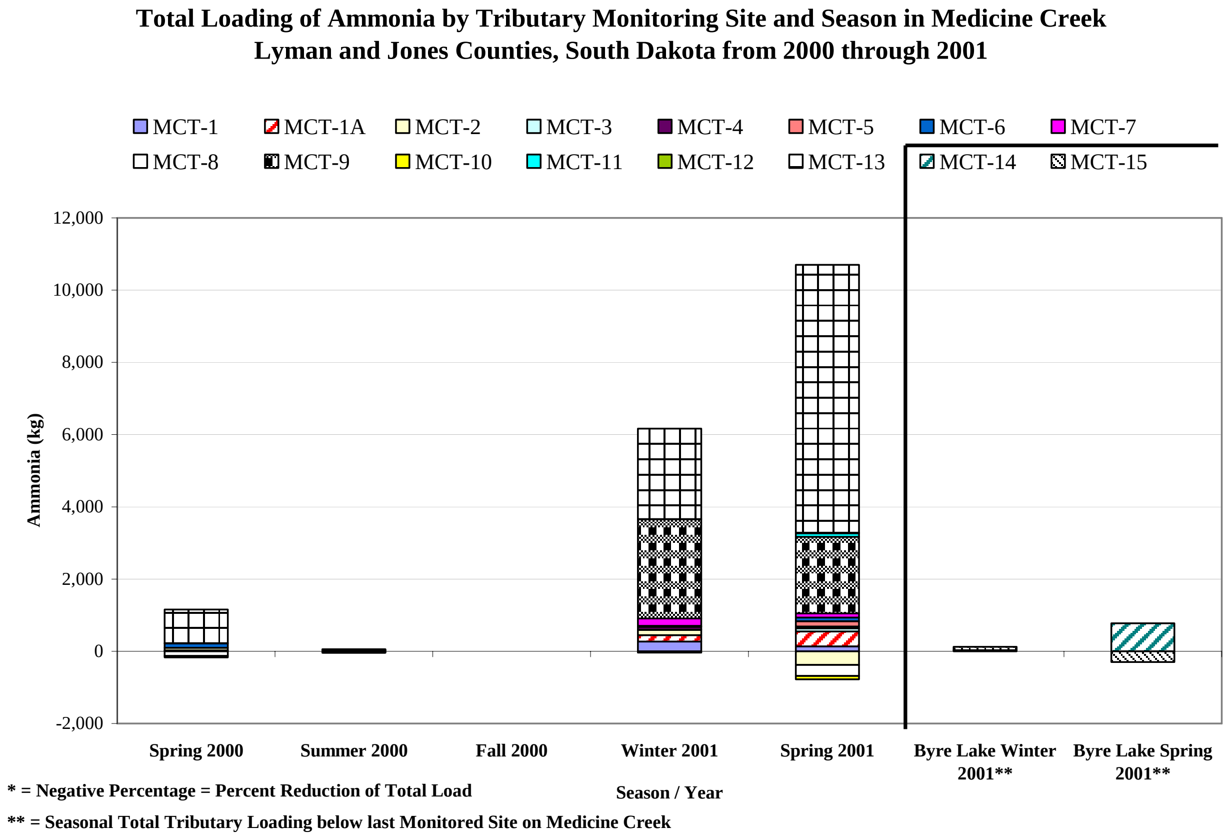


Figure 45. Seasonal Ammonia loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Four sub-watersheds in Medicine Creek (MCT-2, MCT-8, MCT-10 and MCT-15) had overall load reductions in ammonia during the project period. Load reductions were recorded below all reservoir monitoring sites, with load reductions from Fate Dam -0.18 kg/acre, Brakke Dam -0.04 kg/acre and Byre Lake -0.09 kg/acre (Figure 45 and Table 27). Ammonia load reduction potentials recorded at MCT-2 between Vivian and Presho was attributed to the segment being a highly vegetated depositional area conducive to bacterial decomposition of organic matter increasing ammonia production and subsequent ammonia uptake by plants and algae creating an overall reduction during the growing season. Figure 45 seems to support this scenario with no ammonia reductions recorded from any monitoring site in Medicine Creek during the winter sampling season with minimal plant growth. Seasonally, ammonia load reductions were higher in the spring of 2001 at MCT-2 in Medicine Creek and in Byre Lake MCT-15 (Figure 45).

Un-ionized Ammonia

Un-ionized ammonia (NH_4-OH) is the fraction of ammonia that is toxic to aquatic organisms. The concentration of un-ionized ammonia is calculated and is dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic to aquatic organisms. Since pH, temperature and ammonia concentrations are constantly changing, un-ionized ammonia is calculated instantaneously (by sample) to determine compliance with tributary water quality standards rather than from a loading basis.

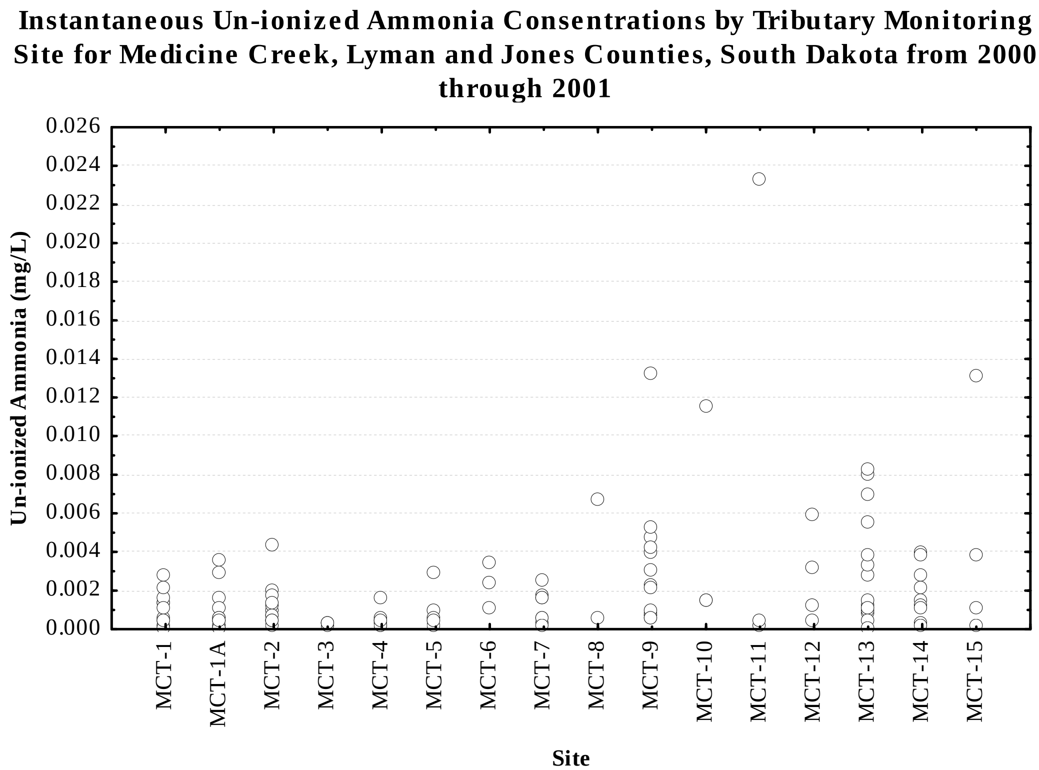


Figure 46. Instantaneous un-ionized ammonia concentrations by site for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The median un-ionized ammonia concentration during Medicine Creek project was 0.001 mg/L (average 0.002 mg/L) with a maximum concentration of 0.022 mg/L recorded at MCT-11 on March 13, 2001 during an increasing flow event (Figure 46). The minimum un-ionized ammonia concentration (0.000083 mg/L) was collected on March 26, 2001 at MCT-4 on Stony Butte Creek (Appendix D). With no violations in un-ionized ammonia concentrations during the project, un-ionized ammonia does not appear to be a problem in Medicine Creek.

Overall, un-ionized ammonia concentrations between sampling sites were significantly different (Table 4); however, not significant enough (p=0.0068) for detecting differences using mean separation procedures (Appendix B, Table B-12).

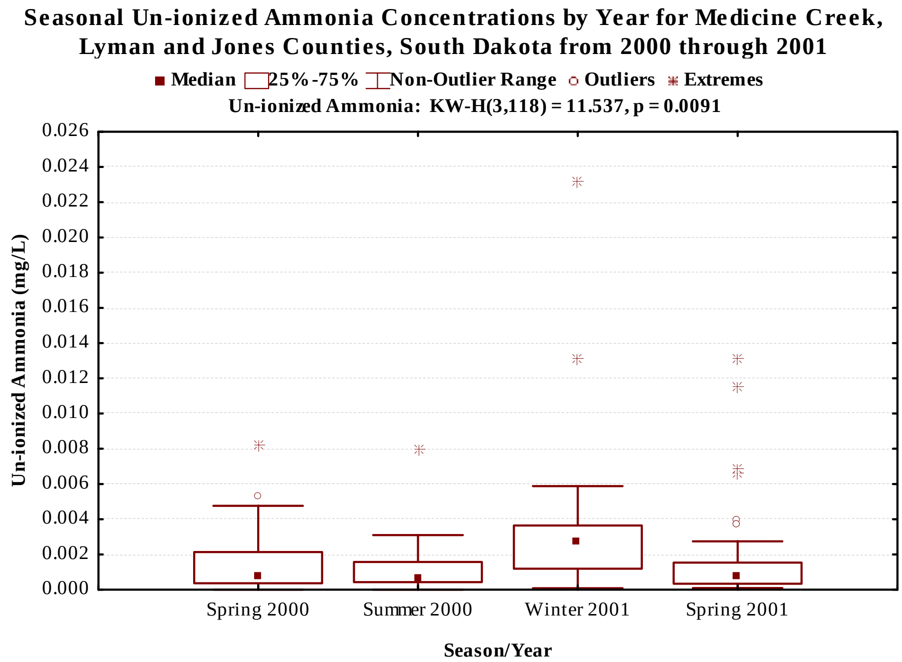


Figure 47. Seasonal un-ionized ammonia concentrations for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

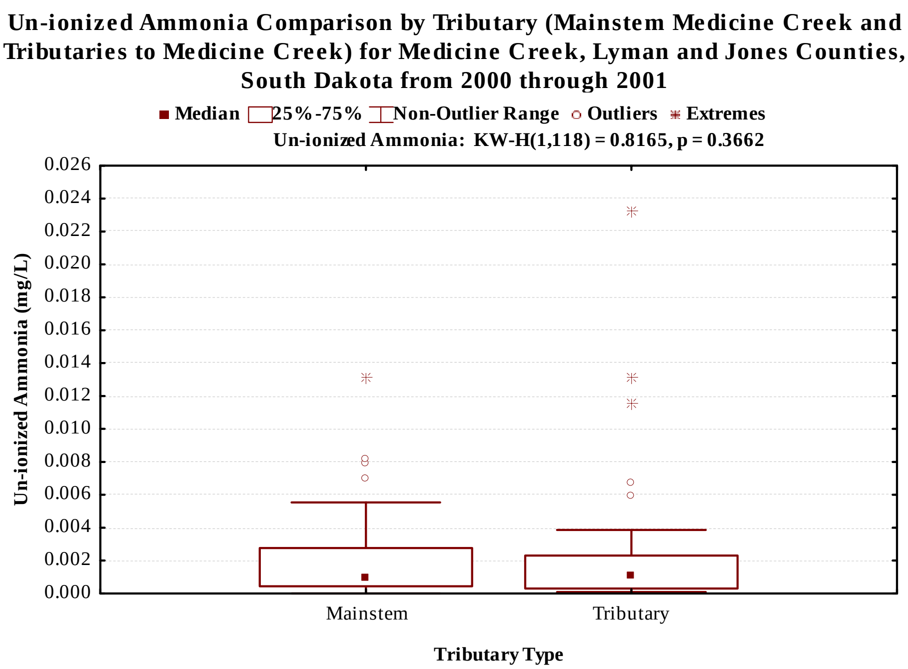


Figure 48. Un-ionized ammonia concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Un-ionized ammonia concentrations were significantly different between sampling seasons (p=0.0091) with concentrations in the winter of 2001 being significantly higher than the spring of 2001 (Figure 47). Mainstem Medicine Creek un-ionized ammonia concentrations were statistically similar (p=0.3662) to concentrations in tributaries to Medicine Creek (Figure 48).

Nitrate-Nitrite

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, precipitation, groundwater, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through de-nitrification by bacteria. This process increases with increasing temperature and decreasing pH. Increased nitrate-nitrite concentrations in mainstem Medicine Creek (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) and upper Nail Creek (MCT-5) were influenced by naturally occurring groundwater/seep nitrate-nitrite concentrations.

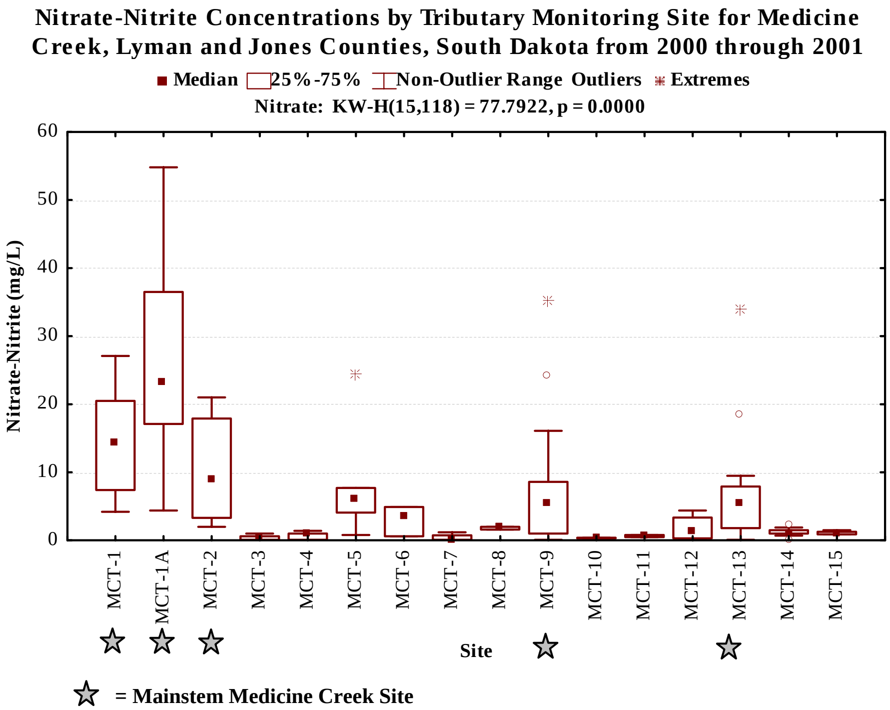


Figure 49. Nitrate-nitrite concentrations by tributary monitoring site in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The median nitrate-nitrite concentration during this project was 3.15 mg/L (average 7.96 mg/L) with a maximum concentration of 54.8 mg/L recorded at MCT-1A on May 31, 2000 during low flow (Figure 49). Minimum nitrate-nitrite concentrations (0.10 mg/L) were collected on a variety of dates from MCT-3, MCT-4, MCT-7, MCT-9, MCT-12 and MCT-13 (Appendix D). Site by site comparison of nitrate and nitrite concentrations indicate that median concentrations in mainstem Medicine Creek and the Nail Creek tributary (MCT-5) were generally high (median value $\geq$ 5.0 mg/L) compared to Stony Butte Creek (MCT-3, MCT-4 and MCT-7), Brakke Creek

(MCT-10, MCT-11 and MCT-12) and Grouse Creek (MCT-14 and MCT-15) with median values ≤ 5.0 mg/L based on data collected from 2000 through 2001 (Figure 49). Nitrate-nitrite concentrations were significantly different between monitoring sites (Figure 49 and Table 4). Mainstem sampling sites MCT-1 and MCT-1A were significantly higher than all Stony Butte Creek sites MCT-3 (p=0.012), MCT-4 (p=0.005) and MCT-7 (p=0.000). MCT-1A nitrate-nitrite concentrations were also significantly higher than MCT-10 Brakke Dam outfall and MCT-14 on Grouse Creek. The only other mainstem monitoring site significantly higher than any upland tributary site was MCT-2 which was higher than MCT-3 and MCT-7 on Stony Butte Creek, South Dakota (Appendix B, Table B-13).

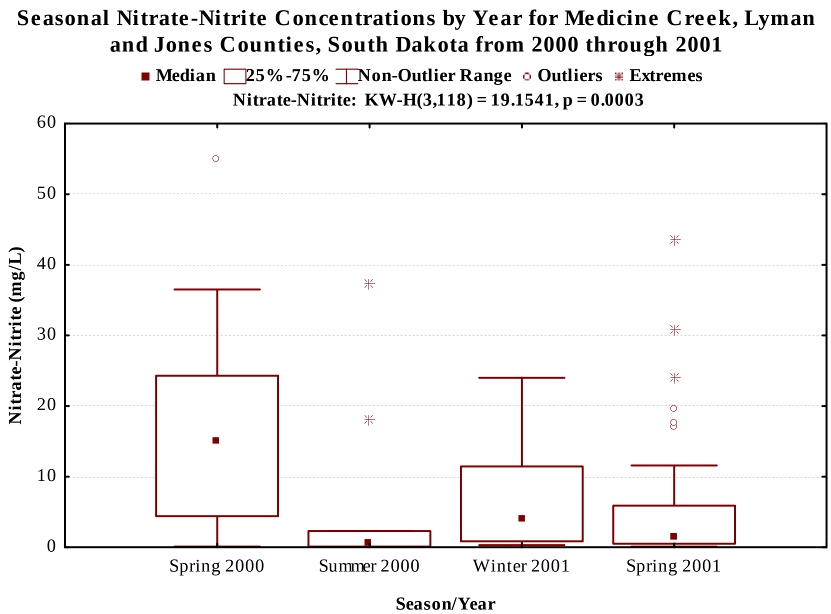


Figure 50. Nitrate-nitrite concentrations by tributary monitoring site in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Nitrate-nitrite concentrations were significantly different between sampling seasons (p=0.0003) with concentrations in the spring of 2000 significantly higher than the summer of 2000 and the spring of 2001 (Figure 50).

Mainstem Medicine Creek, has over time, down cut and meandered into banks exposing primary bedrock (Pierre shale), which under certain conditions, can be high in dissolved minerals (TDS, nitrate-nitrite, sulfate, sodium and selenium concentrations) resulting in increased specific conductance values that are natural in various locations throughout the Pierre Shale formation Data from other study locations in the Pierre Shale formation such as Freeman Dam and Hayes Lake/Frozen Man Creek, support this hypothesis. SD DENR Geological Survey on Freeman Dam detected high nitrate-nitrite, sulfate, sodium and selenium concentrations in well and seep samples collected in the watershed (Table 20). Lorenzen et al., 2004 indicate periodic high elevated nitrate-nitrite concentrations in the Frozen Man Creek/Hayes Lake watershed may have origins in geologic formations. Soils in the Frozen Man Creek/Hayes Lake watershed developed from Pierre shale. Layers have been identified in the bedded material that are high in nitrate and contribute nitrate-nitrites to groundwater that seeps through these areas. The Pierre Shale soils have a history of seeps developing and enlarging where native range has been converted to cropland. This may be caused where the annual moisture exceeds the cropland needs and a water table develops bringing seep water to the ground surface. However, increased nitrate-nitrite concentrations in mainstem Medicine Creek appear be attributed to streambed down cutting exposing mainstem Medicine Creek to Pierre Shale and groundwater seeps increased nitrate-nitrite and TDS concentrations resulting in increased specific conductance values in Medicine Creek, especially in upper mainstem Medicine Creek (MCT-1, MCT-1A and MCT-2).

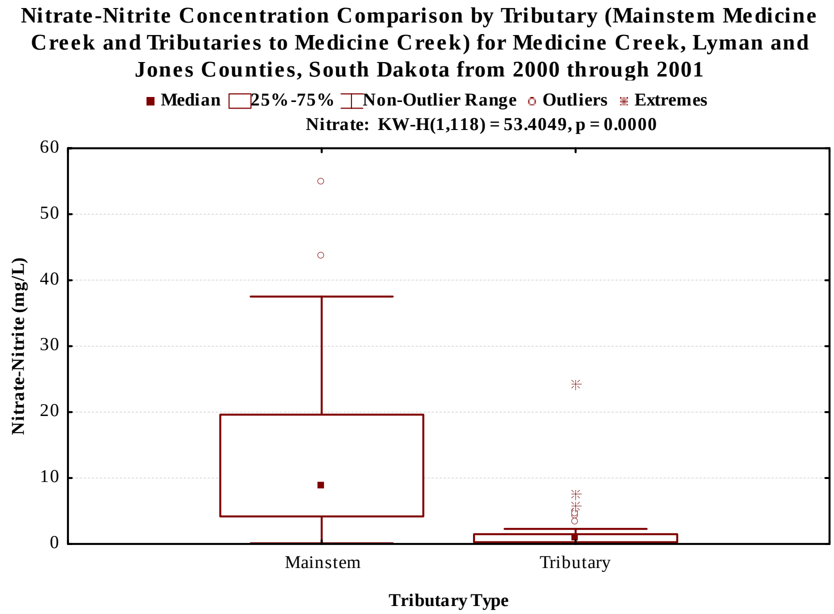


Figure 51. Nitrate-Nitrite concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

These conclusions tend to support the data observed in mainstem Medicine Creek. Increased nitrate-nitrite concentrations in mainstem Medicine Creek, exposed to and influenced by the Pierre Shale formation, especially during groundwater dominated base flow were statistically higher (p=0.0000) than concentrations in most surface water dominated upland tributaries to Medicine Creek (Figure 51).

Thus increased nitrate-nitrite and TDS concentrations resulting in increased specific conductance values in Medicine Creek, especially in upper mainstem Medicine Creek (MCT-1, MCT-1A and MCT-2), are caused by natural processes in Pierre Shale influencing surface water nitrate-nitrite concentrations in the watershed and should be considered a natural condition.

Table 28. Nitrate-nitrite loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Nitrate-Nitrite Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	3,723	0.07	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	78,045	2.43	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-16,336	-	-0.73	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	642	0.02	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	1,306	0.06	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	4,315	0.36	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	-62,414	-	-2.00	Possible algal uptake, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	7,966	1.00	-	
Nail Creek	**MCT-6**	7,451	8.5%	-1,847	-	-0.25	Vegetated pond with algae above monitoring site
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-7,671	-	-3.97	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	910	0.08	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	93	0.03	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-684	-	-0.75	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	-12,319	-	-0.28	Possible algal uptake, pooled section of stream
Gauged Watershed Total		**286,358**	100.0%	81,738	0.29	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	806	0.04	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-203		-0.09	Reservoir
Total Monitored Area		310,534	100.0%	89,684	0.29		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Nitrate-nitrite loading by site was highest at site MCT-1A (78,045 kg) comprising 95.5 percent of the nitrate-nitrite load in Medicine Creek and 18.7 percent of the hydrologic load (Table 28). The source of the nitrate-nitrite appears to be from the naturally occurring Pierre Shale formation and overlying soils derived from Pierre Shale. Naturally occurring high nitrate-nitrite concentrations in the Pierre Shale formation have been recorded in other locations throughout the formation (Freeman Dam (Jackson County, Table 20) and Frozen Man Creek (Stanley County, South Dakota) known to contain high concentrations of nitrate-nitrite. Tributary nitrate-nitrite loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake watersheds (Figure 52). Overall nitrate-nitrite loading between sampling sites was significantly different (Table 4); however, not significant enough (p=0.0369) for detecting differences using mean separation procedures (Appendix B, Table B-26). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-1A sub-watershed (2.43 kg/acre) followed by MCT-5 (upper Nail Creek) at 1.00 kg/acre (Table 28).

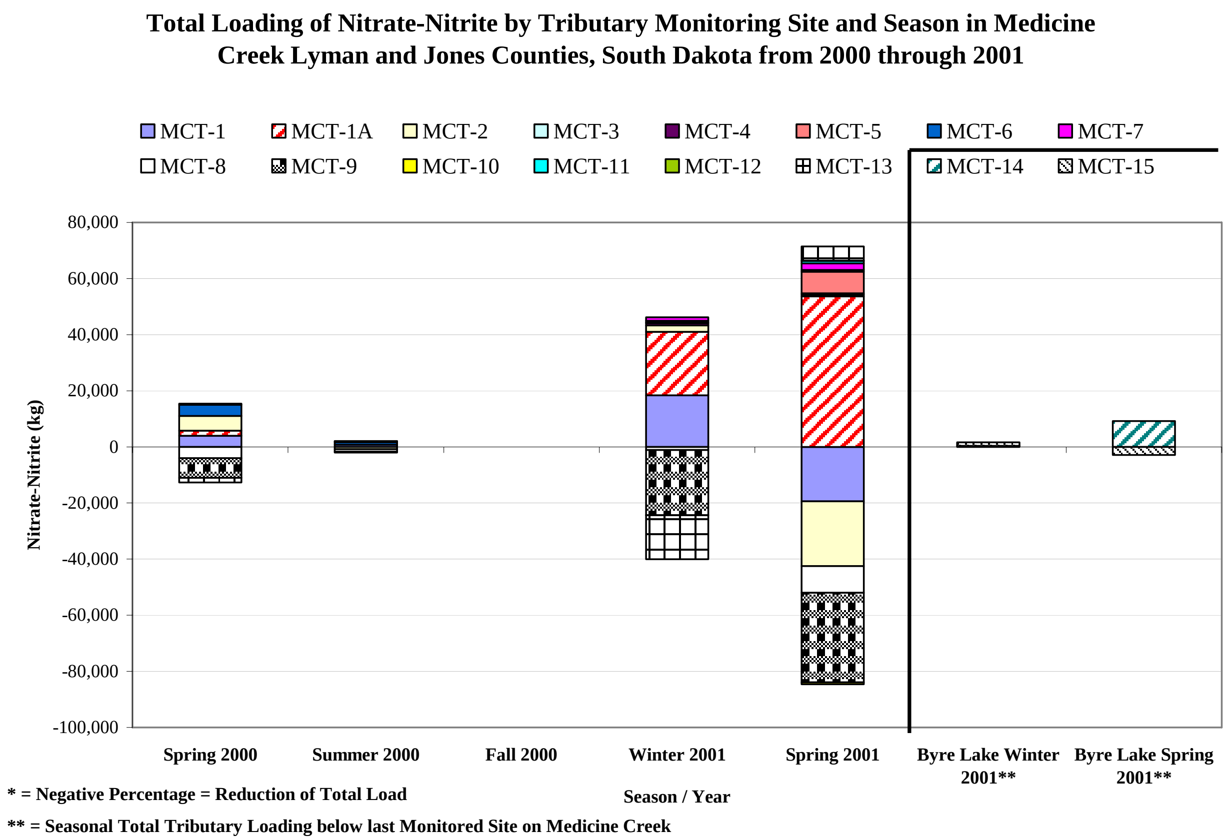


Figure 52. Seasonal nitrate-nitrite loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Seven sub-watersheds in Medicine Creek had overall load reductions in nitrate-nitrite during the project period, MCT-2, MCT-6, MCT-8, MCT-9, MCT-10 and MCT-15. Similar to other parameters, three of the seven annual load reductions by sub-watershed occurred at MCT-8 (-3.97 kg/acre), MCT-10 (-0.75 kg/acre) and MCT-15 (-0.09 kg/acre) all three monitoring sites were directly downstream of Fate Dam, Brakke Dam and Byre Lake, respectively. Reductions in nitrate-nitrite may have been from phytoplankton, hydrophytes and bacteria converting and reducing and assimilating nitrate into other forms (Table 28). Nitrate-nitrite load reduction at mainstem monitoring sites (MCT-2, MCT-9 and MCT-13) were attributed to dense hydrophytes (cattails, *Typha* spp.) at MCT-2 and algae dominated ponded water during low flow/base flow conditions at MCT-9 and MCT-13. MCT-6 (Nail Creek before it enters Fate Dam) initially receives the second largest annual per acre load of nitrate (1.00 kg/acre) from MCT-5 (upper Nail Creek) in the Medicine Creek watershed. Nitrate-nitrite load reduction observed at MCT-6 was attributed to dense cattail stands in and around an algal dominated ponded reach above MCT-6. Some stream reaches in the MCT-6 sub-watershed were also heavily dominated by hydrophytes increasing the potential for nitrate-nitrite uptake.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is organic nitrogen including ammonia. Sources of TKN can include live organic matter, release from dead or decaying organic matter, septic systems or agricultural waste.

The median TKN concentration in Medicine Creek was 1.46 mg/L (average 1.61 mg/L) and had a maximum concentration of 6.63 mg/L recorded at MCT-9 on March 13, 2001 during high flow (Figure 53). Minimum TKN concentration (0.18 mg/L) was collected at MCT-15 (Byre Lake outfall) on April 10, 2001 (Appendix D).

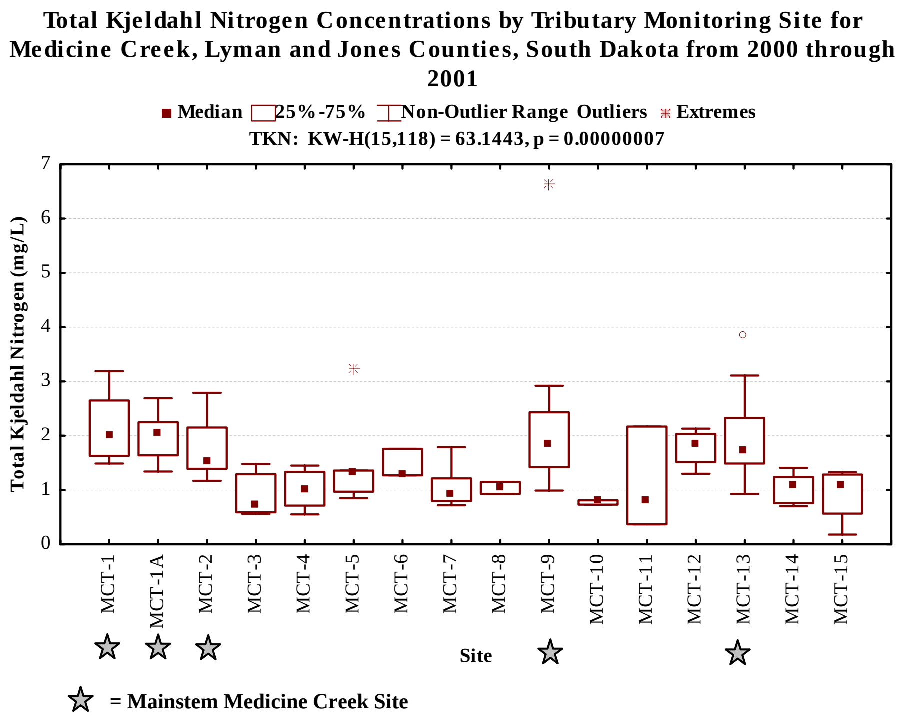


Figure 53. Total Kjeldahl Nitrogen concentrations by tributary monitoring site in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

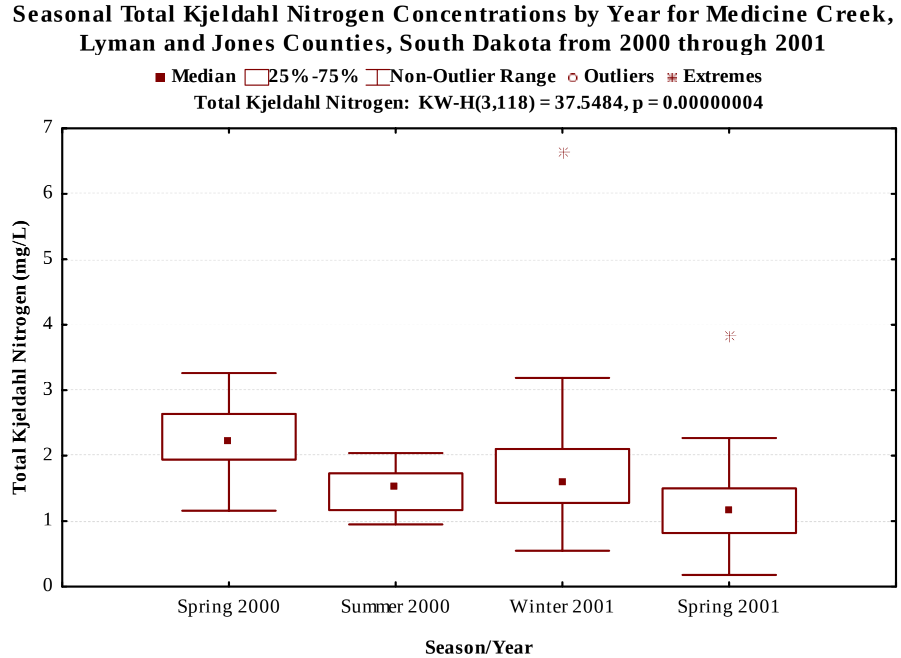


Figure 54. Monthly Total Kjeldahl Nitrogen concentrations and estimated loads to Medicine Creek and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

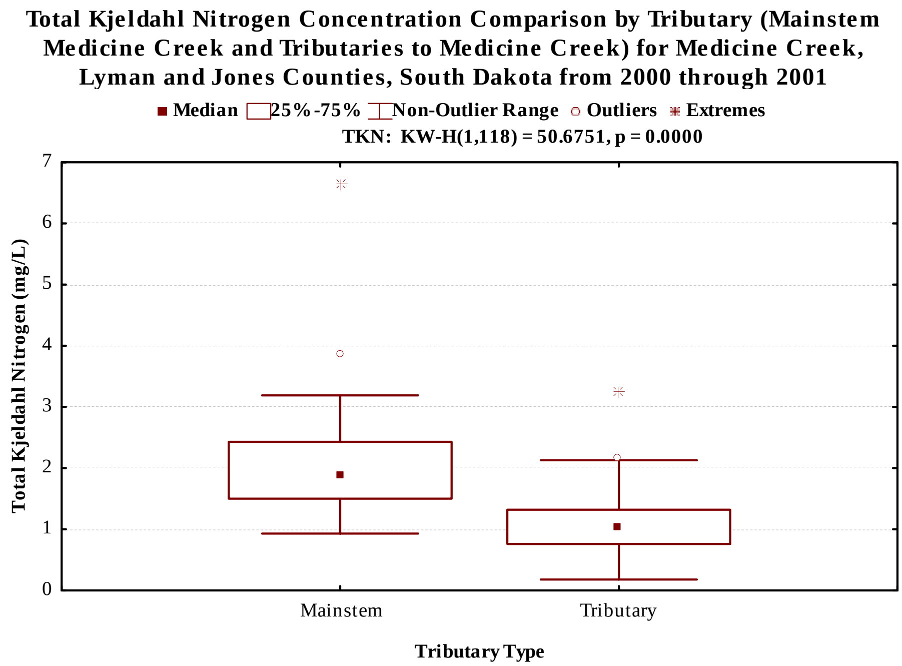


Figure 55. Total Kjeldahl Nitrogen concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 29. Total Kjeldahl Nitrogen loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Kjeldahl Nitrogen Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	10,311	0.19	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	8,378	0.26	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-6,104	-	-0.27	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	1,059	0.03	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	1,603	0.07	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	1,525	0.13	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	9,299		0.30	Slack water, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	1,803	0.23	-	
Nail Creek	**MCT-6**	7,451	8.5%	2,616	0.35	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-3,057	-	-1.58	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	959	0.08	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	256	0.08	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-508	-	-0.55	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	42,443	0.96	-	
Gauged Watershed Total		**286,358**	100.0%	80,764	0.28	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	8,381	0.38	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-2,256		-1.03	Reservoir
Total Monitored Area		310,534	100.0%	86,890	0.28		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Site by site comparison of TKN concentrations indicate that median concentrations in mainstem Medicine Creek and the Nail Creek tributary generally ranged from one to two milligrams per liter, except for MCT-3 and MCT-7 on Stony Butte Creek, MCT-10 Brakke Dam outfall and MCT-11 the west branch of Brakke Creek (Figure 53).

TKN concentrations were significantly different between monitoring sites (Figure 53 and Table 4). Mainstem sampling site MCT-1 was significantly higher than upland tributaries MCT-3 (p=0.0143), MCT-4 (p=0.0253), MCT-7 (p=0.0273) on Stony Butte Creek and MCT-14 (p=0.0103) on Grouse Creek. The North Fork of Medicine Creek (MCT-1A) was also significantly higher than MCT-3 (p=0.0279) on Stony Butte Creek and MCT-14(p=0.021) on the inlet to Byre Lake (Appendix B, Table B-14).

TKN concentrations were significantly different between sampling seasons (p=0.0000) with concentrations collected in the winter of 2001 and the spring of 2000 significantly higher than the spring of 2001 and was may be due to lower flows (Figure 54). Mainstem Medicine Creek TKN concentrations were statistically higher (p=0.0000) than concentrations in tributaries to Medicine Creek (Figure 55).

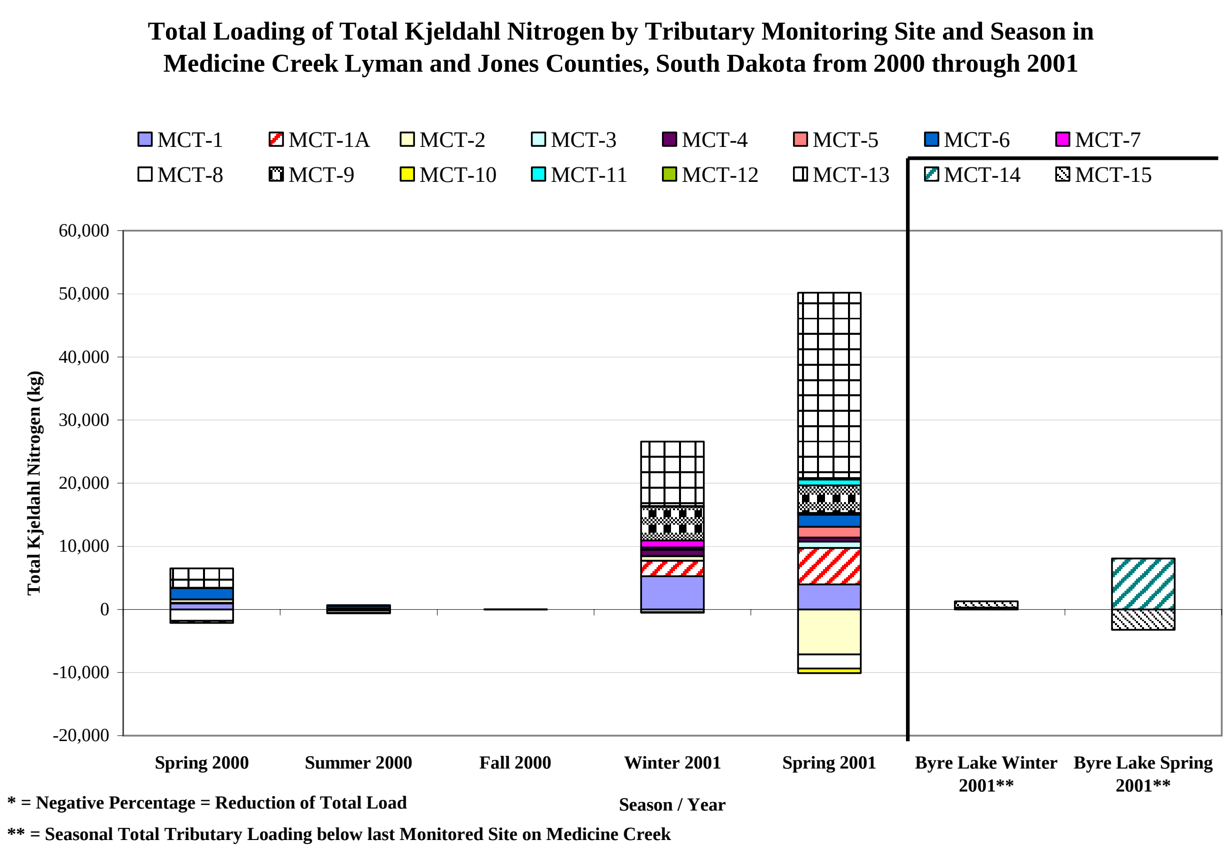


Figure 56. Seasonal Total Kjeldahl Nitrogen loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

TKN loading by site was highest at site MCT-13 (42,443 kg) comprising 52.6 percent of the TKN load in Medicine Creek and 15.1 percent of the hydrologic load (Table 29). Tributary TKN loading by season was highest in the spring of 2001 for both Medicine Creek (MCT-13) and Byre Lake (MCT-14) watersheds (Figure 56). Overall TKN loading between sampling sites was not significantly different (p=0.223) during the project (Table 4 and Appendix B, Table B-27). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed near Kennebec, South Dakota (0.96 kg/acre) followed by MCT-14 (Grouse Creek) northeast of Kennebec at 0.38 kg/acre (Table 29).

Five sub-watersheds in Medicine Creek had overall load reductions in TKN during the project period, MCT-2, MCT-8, MCT-9 MCT-10 and MCT-15. As with most parameters, the three monitoring sites directly downstream of Fate Dam, Brakke Dam and Byre Lake had annual load reductions by sub-watershed (MCT-8 (-1.58 kg/acre), MCT-10 (-0.55 kg/acre) and MCT-15 (-1.03 kg/acre), respectively). TKN load reductions may have been caused from settling, deposition or biological conversion of TKN into ammonia for plant growth (Table 29). Load reduction at mainstem monitoring site MCT-2 was attributed to dense hydrophytes (cattails, *Typha* spp.) and slack water increasing bacterial reduction of TKN to ammonia and subsequent assimilation by plants and algae for growth. Like the load reductions observed in sub-watersheds with lakes, load reduction at MCT-9, a ponded reach with algae and some hydrophytes during low flows, was also attributed to settling, deposition and biological conversion reducing TKN loads in this reach.

Organic Nitrogen

Organic nitrogen is calculated using TKN and ammonia (TKN minus ammonia). Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen by bacteria. Since organic nitrogen is calculated using TKN and ammonia concentrations are low, organic nitrogen graphs and loading tables are similar to those for TKN.

The median organic nitrogen concentration in Medicine Creek was 1.38 mg/L (average 1.50 mg/L). The maximum concentration of 4.77 mg/L was recorded at MCT-9 on March 13, 2001 during high flow (Figure 57). Minimum organic nitrogen concentration (0.36 mg/L) was collected at MCT-11 (west tributary of Brakke Creek) on April 25, 2001 (Appendix D). Site by site comparison of organic nitrogen concentrations indicate that median concentrations in mainstem Medicine Creek generally ranged from one to two milligrams per liter, while most upland tributaries, except for MCT-12, hovered around one milligram per liter (Figure 57).

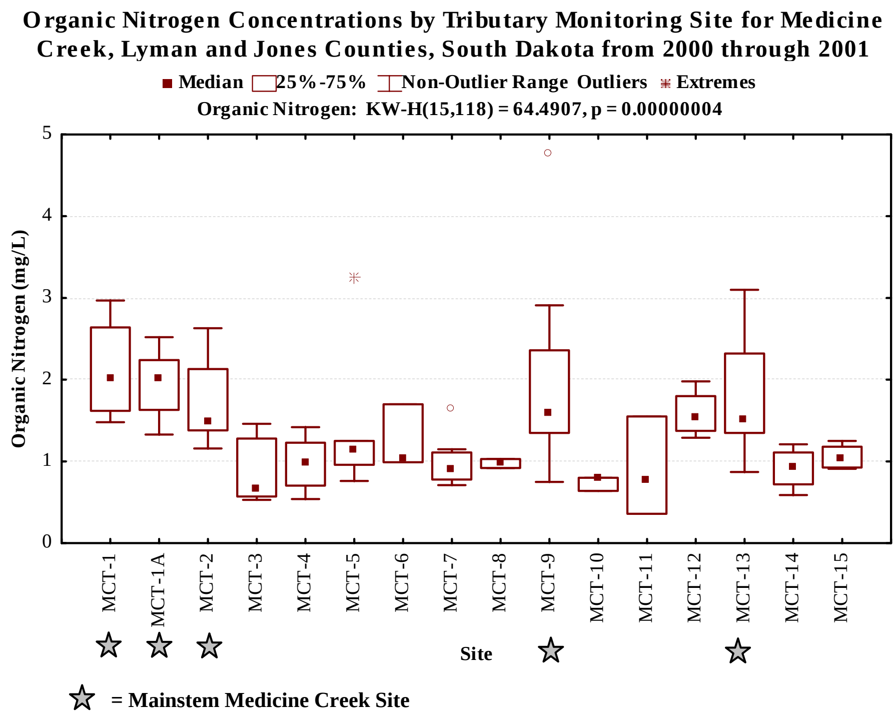


Figure 57. Organic nitrogen concentrations by tributary monitoring site for Medicine Creek, Lyman County, South Dakota from 2000 through 2001.

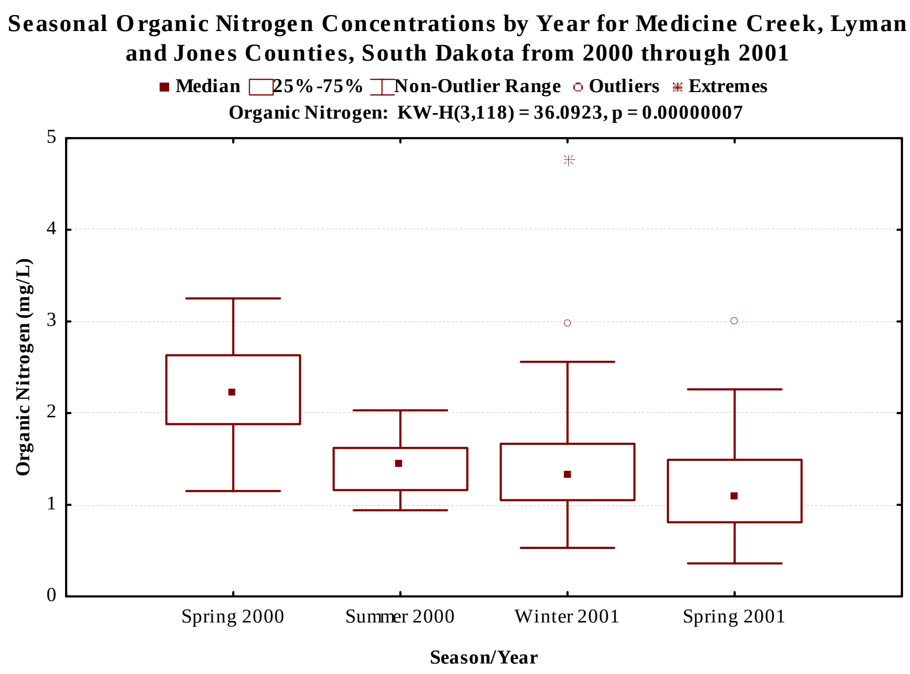


Figure 58. Seasonal organic nitrogen concentrations for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Organic nitrogen concentrations were significantly different (p=0.0000) between monitoring sites (Figure 57 and Table 4). Mainstem sampling site MCT-1 and MCT-1A were significantly higher than upland tributaries MCT-3, MCT-4, MCT-7 on Stony Butte Creek and MCT-14 on Grouse Creek (Appendix B, Table B-15).

Organic nitrogen concentrations were significantly different between sampling seasons (p=0.0000) with concentrations collected in the spring of 2000 significantly higher than the winter and spring of 2001 (Figure 58). Mainstem Medicine Creek organic nitrogen concentrations were statistically higher (p=0.0000) than concentrations in tributaries to Medicine Creek (Figure 59).

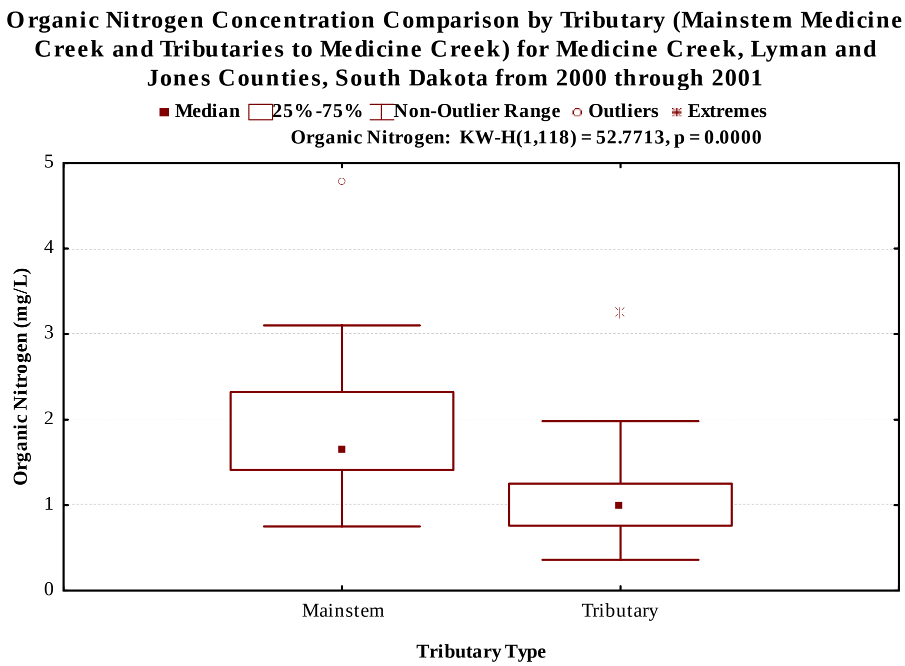


Figure 59. Organic Nitrogen concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 30. Organic nitrogen loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Organic Nitrogen Sub-watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	9,877	0.18	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	7,780	0.24	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-5,573	-	-0.25	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	971	0.03	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	1,467	0.06	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	931	0.08	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	4,389		0.14	Slack water, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	1,652	0.21	-	
Nail Creek	**MCT-6**	7,451	8.5%	2,491	0.33	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-2,688	-	-1.39	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	859	0.07	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	236	0.08	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-538	-	-0.59	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	35,045	0.79	-	
Gauged Watershed Total		**286,358**	100.0%	66,329	0.23	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	7,574	0.34	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-1,218		-0.56	Reservoir
Total Monitored Area		310,534	100.0%	72,685	0.23		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Organic nitrogen loading by site was highest at site MCT-13 (35,045 kg) comprising 52.8 percent of the organic nitrogen load in Medicine Creek with 15.1 percent of the hydrologic load (Table 30). Like TKN, tributary organic nitrogen loading by season was highest in the spring of 2001 for both Medicine Creek and Byre Lake watersheds (Figure 60). Overall organic nitrogen loading between sampling sites was not significantly different (p=0.1846) during 2000 and 2001 (Appendix B, Table B-28 and Table 4). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed near Kennebec, South Dakota (0.79 kg/acre) followed by MCT-14 (Grouse Creek) northeast of Kennebec at 0.34 kg/acre (Table 30).

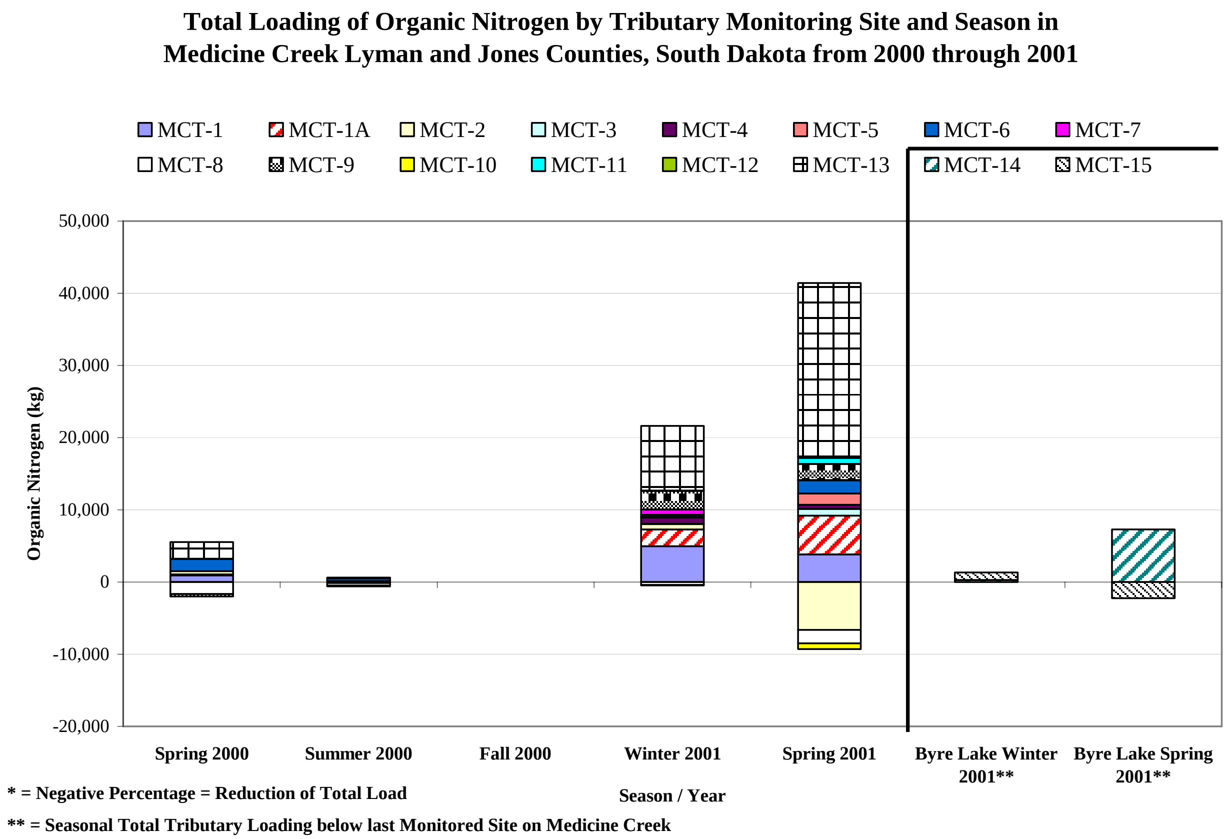


Figure 60. Seasonal organic nitrogen loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Again like TKN, five sub-watersheds in Medicine Creek had overall load reductions in organic nitrogen during the project period, MCT-2, MCT-8, MCT-9 MCT-10 and MCT-15. Three of the five annual load reductions by sub-watershed occurred at MCT-8 (-1.59 kg/acre), MCT-10 (-0.59 kg/acre) and MCT-15 (-0.56 kg/acre) all three monitoring sites were directly downstream of Fate Dam, Brakke Dam and Byre Lake, respectively, where settling, deposition and biological conversion can reduce organic nitrogen loading (Table 30). Similar to the load reductions observed in sub-watersheds with lakes, load reduction at MCT-9, a ponded reach with algae and some hydrophytes during low flows, was probably due to settling, deposition and biological conversion reducing organic nitrogen loads in this reach. Load reduction at MCT-2 was attributed to deposition and dense vegetation in the stream channel where bacterial decomposition reduces organic nitrogen to ammonia which then assimilates the available ammonia for plant growth.

Inorganic Nitrogen

Inorganic nitrogen is calculated by summing ammonia and nitrate-nitrite. Inorganic nitrogen is readily assimilated by plants.

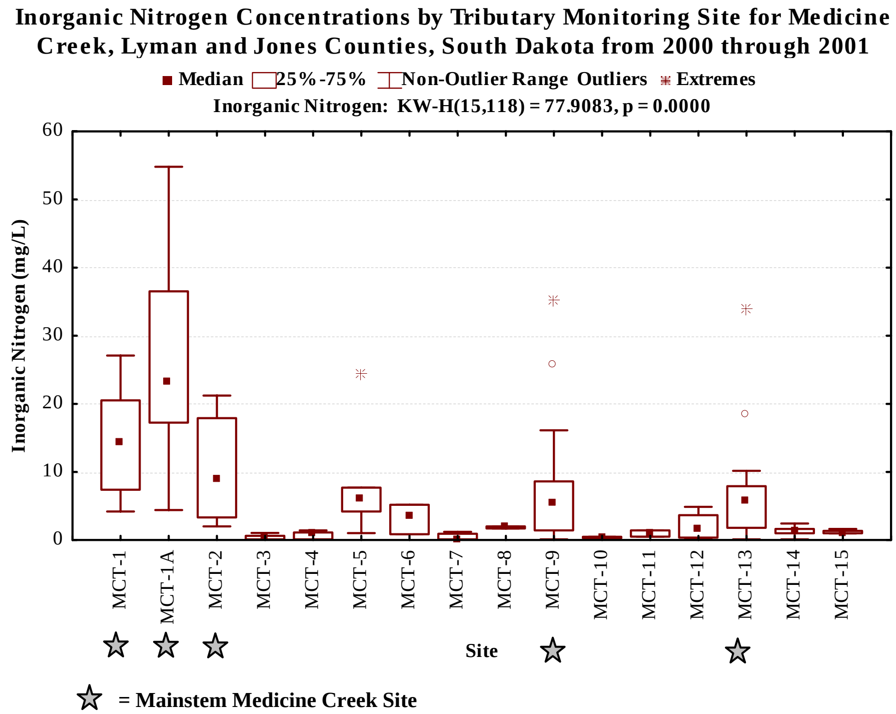


Figure 61. Inorganic nitrogen concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

The median inorganic nitrogen concentration in Medicine Creek was 3.17 mg/L (average 8.08 mg/L). The maximum concentration of 54.81 mg/L was recorded at MCT-1A on May 31, 2000 during low flows (Figure 61). The minimum inorganic nitrogen concentration of 0.11 mg/L was collected from a variety of sampling sites throughout the watershed (MCT-4, MCT-7, MCT-9, MCT-12, MCT-13 and MCT-14) in 2000 and 2001 (Appendix D). Site by site comparison of inorganic nitrogen concentration indicated that median concentrations in mainstem Medicine Creek and the Nail Creek tributary (MCT-5) were generally high (median value $\geq$ 5.0 mg/L) compared to Stony Butte (MCT-3, MCT-4 and MCT-7), Brakke (MCT-10, MCT-11 and MCT-12) and Grouse Creeks (MCT-14 and MCT-15) with median values $\leq$ 5.0 mg/L (Figure 61). Figure 61 (inorganic nitrogen) was similar to Figure 49 (nitrate-nitrite) because nitrate-nitrite make up 98.6 percent the of the inorganic nitrogen total. As previously discussed, high nitrate-nitrate concentrations especially in mainstem Medicine Creek were due to high natural back ground concentrations originating from the Pierre Shale formation, especially during low flow conditions.

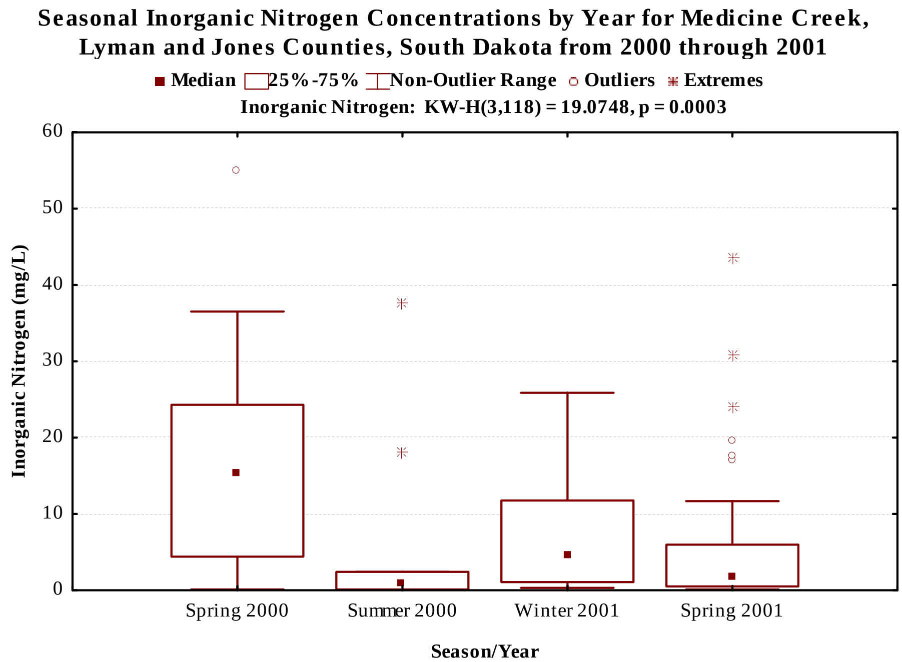


Figure 62. Seasonal inorganic nitrogen concentrations for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

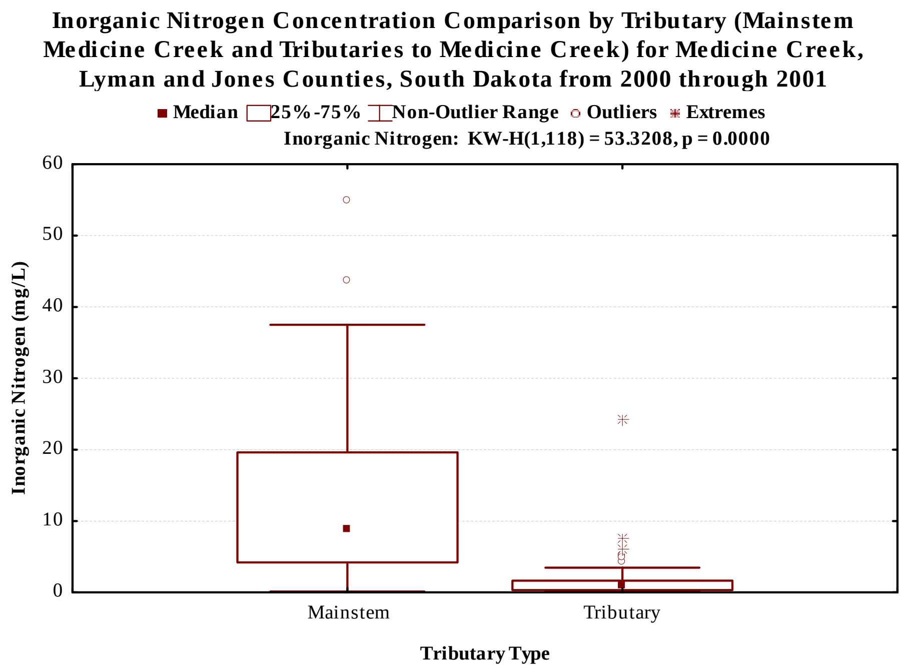


Figure 63. Inorganic Nitrogen concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 31. Inorganic nitrogen loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Inorganic Nitrogen Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	20,986	0.38	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	79,376	2.47	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-16,931	-	-0.75	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	730	0.02	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	1,436	0.06	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	4,661	0.39	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	-76,040		-2.44	Possible algal uptake, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	8,117	1.02	-	
Nail Creek	**MCT-6**	7,451	8.5%	-1,722	-	-0.23	Vegetated pond with algae above monitoring site
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-8,010	-	-4.15	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	1,004	0.09	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	112	0.04	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-646	-	-0.70	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	-1,024	-	-0.023	Possible algal uptake, pooled section of stream
Gauged Watershed Total		**286,358**	100.0%	99,541	0.35	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	10,348	0.47	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-1,280		-0.59	Reservoir
Total Monitored Area		310,534	100.0%	108,609	0.35		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Inorganic nitrogen concentrations were significantly different between monitoring sites (Figure 61 and Table 4). Mainstem sampling sites MCT-1, MCT-1A and MCT-2 were significantly higher than all Stony Butte Creek sites MCT-3, MCT-4 and MCT-7. MCT-1A nitrate-nitrite concentrations were also significantly higher than MCT-10 Brakke Dam outfall and MCT-14 on Grouse Creek (Appendix B, Table B-16).

Inorganic nitrogen concentrations were significantly different between sampling seasons (p=0.0003) with concentrations collected in the spring of 2000 significantly higher than the summer of 2000 and spring of 2001 (Figure 62). Similar to nitrate-nitrite concentrations, mainstem Medicine Creek inorganic nitrogen concentrations were statistically higher (p=0.0000) than concentrations in upland tributaries to Medicine Creek (Figure 63).

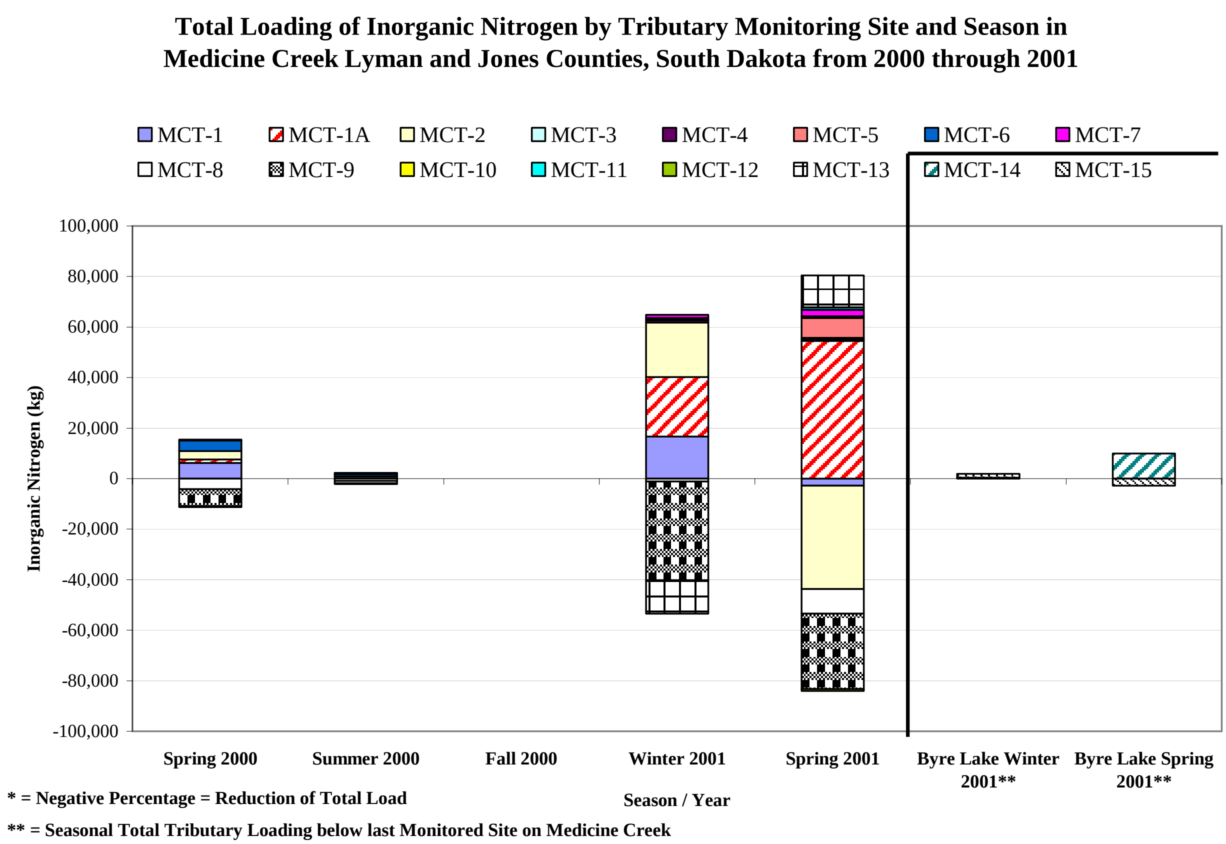


Figure 64. Seasonal inorganic nitrogen loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Inorganic nitrogen loading by site was highest at site MCT-1A (79,376 kg) comprising 79.7 percent of the inorganic nitrogen load in Medicine Creek and 18.7 percent of the hydrologic load (Table 31). Tributary inorganic nitrogen loading by season was highest in the spring of 2001 in the Medicine Creek and Byre Lake watersheds (Figure 64). Overall inorganic nitrogen loading between sampling sites was significantly different (Table 4); however, not significant enough (p=0.0433) for detecting differences using mean separation procedures (Appendix B, Table B-

29). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-1A sub-watershed (2.47 kg/acre) followed by MCT-5 (upper Nail Creek) at 1.02 kg/acre (Table 31).

Similar to nitrate-nitrite loading, seven sub-watersheds in Medicine Creek had overall load reductions in inorganic nitrogen during the project period, MCT-2, MCT-6, MCT-8, MCT-9 MCT-10, MCT-13 and MCT-15. Three of the seven annual load reductions by sub-watershed occurred at Fate Dam MCT-8 (-4.15 kg/acre), Brakke Dam MCT-10 (-0.70 kg/acre) and Byre Lake MCT-15 (-0.59 kg/acre), where phytoplankton, hydrophytes and bacteria can convert, reduce and assimilate inorganic nitrogen (ammonia and nitrate) into other forms (Table 31). Inorganic nitrogen load reduction at mainstem monitoring sites (MCT-2, MCT-9 and MCT-13) was attributed to dense hydrophytes at MCT-2 and algae dominated ponded water at MCT-9 and MCT-13. MCT-6 (Nail Creek before it enters Fate Dam) initially receives the second largest annual per acre load of inorganic nitrogen (1.02 kg/acre) from MCT-5 (upper Nail Creek) in the Medicine Creek watershed. Inorganic nitrogen load reduction observed at MCT-6 was attributed to dense cattail stands in and around an algal dominated ponded reach above MCT-6 utilizing nitrogen compounds and reducing nitrogen loads at MCT-6. Some stream reaches in the MCT-6 sub-watershed were also heavily dominated by hydrophytes increasing the potential for inorganic nitrogen uptake.

Total Nitrogen

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient (nitrogen or phosphorus) for growth and will be discussed later in this section of report (page 121).

The maximum total nitrogen concentration found in Medicine Creek was 57.33 mg/L at MCT-1A on May 31, 2000 (Figure 65 and Appendix D). The median concentration for the entire project was 4.76 mg/L (average 9.56 mg/L) with a standard deviation of 11.4 mg/L. The minimum total nitrogen concentration was recorded at MCT-15, Byre Lake outfall (0.17 mg/L) on April 10, 2001. The organic nitrogen fraction (percent of organic nitrogen in total nitrogen (concentrations)) ranged from 3.6 percent to 93.5 percent and averaged 15.4 percent, while the inorganic nitrogen fraction ranged from 6.5 percent to 96.4 percent and averaged 84.6 percent. Seasonally, average total nitrogen concentrations were higher in the summer of 2000 during low flow conditions (Table 15).

Total nitrogen concentrations were significantly different between monitoring sites (Figure 65 and Table 4). Mainstem sampling sites MCT-1 and MCT-1A were significantly higher than all Stony Butte Creek sites MCT-3, MCT-4 and MCT-7, the outfall of Brakke Dam MCT-10 while only MCT-1A was significantly higher than MCT-14 the inlet to Byre Lake MCT-14 and MCT-15 Byre Lake outfall on Grouse Creek (Appendix B, Table B-17). The only other monitoring site that was significantly different was MCT-2 on mainstem Medicine Creek which had higher total nitrogen concentrations than Stony Butte Creek sites MCT-3 and MCT-7.

Total nitrogen concentrations were significantly different between sampling seasons ($p=0.0001$) with concentrations collected in the spring of 2000 significantly higher than the summer of 2000 and spring of 2001 sampling seasons (Figure 66). Mainstem Medicine Creek total nitrogen concentrations were statistically higher ($p=0.0000$) than concentrations in upland tributaries to Medicine Creek (Figure 67).

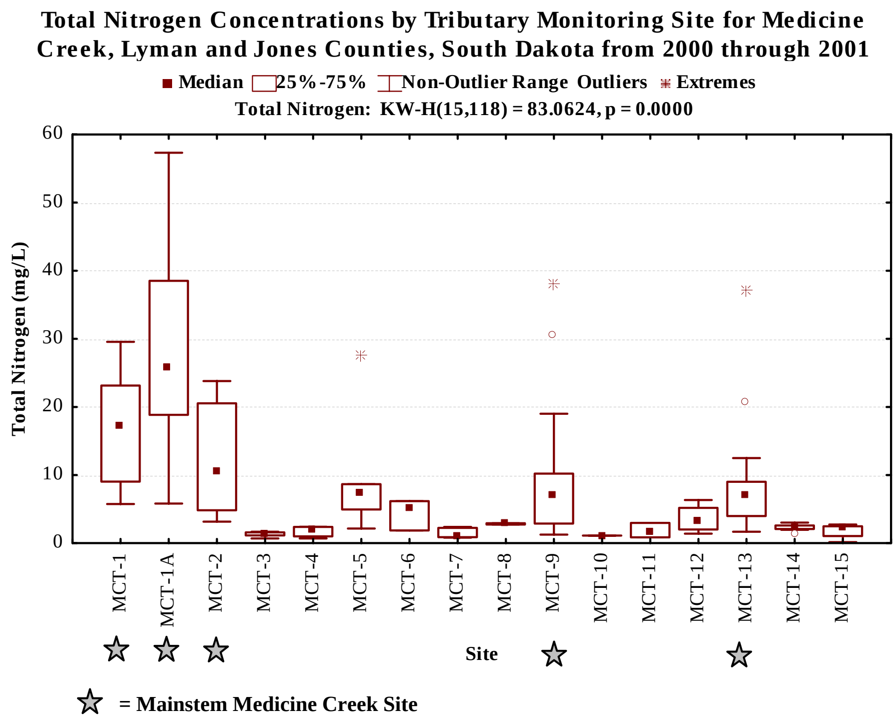


Figure 65. Total nitrogen concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

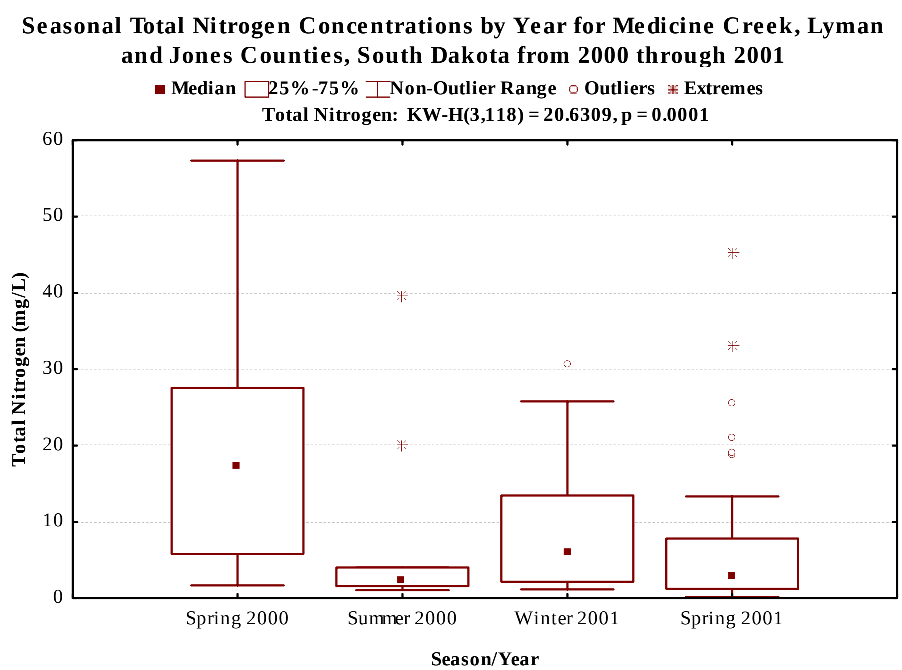


Figure 66. Seasonal total nitrogen concentrations for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

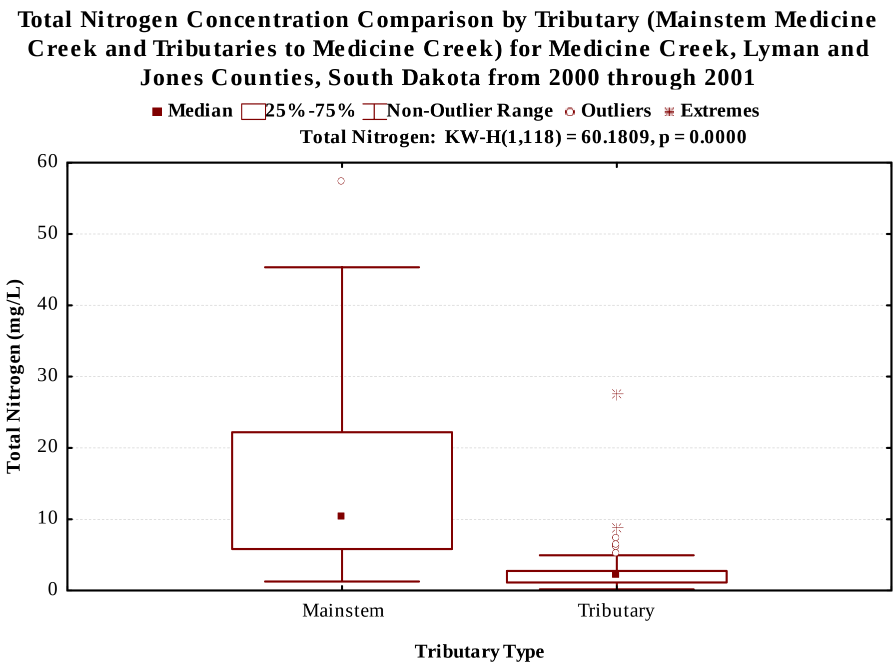


Figure 67. Total nitrogen concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total nitrogen loading by site was highest at site MCT-1A (87,155 kg) comprising 55.6 percent of the total nitrogen load in Medicine Creek and 18.7 percent of the hydrologic load (Table 32). 89.6 percent of the total nitrogen fraction in sub-watershed MCT-1A (78,045 kg) was nitrate-nitrite loading originating from the Pierre Shale formation with high natural back ground concentrations of nitrate-nitrite. Tributary total nitrogen loading by season was highest in the spring of 2001 for the Medicine Creek and Byre Lake watersheds (Figure 68). Overall total nitrogen loading between sampling sites were statistically similar (p=0.0707) in the Medicine Creek watershed (Table 4 and Appendix B, Table B-30). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-1A sub-watershed (2.71 kg/acre) followed by MCT-5 (upper Nail Creek) at 1.22 kg/acre (Table 32).

Table 32. Total nitrogen loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Nitrogen Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	30,863	0.56	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	87,155	2.71	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-22,863	-	-1.02	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	1,717	0.05	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	2,877	0.13	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	7,088	0.59	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	-72,779		-2.33	Slack water, pooled section of stream
Upper Nail Creek	**MCT-5**	7,975	7.1%	9,769	1.22	-	
Nail Creek	**MCT-6**	7,451	8.5%	769	0.10	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-10,705	-	-5.54	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	1,862	0.16	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	357	0.12	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-1,194	-	-1.30	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	24,818	0.56	-	
Gauged Watershed Total		**286,358**	100.0%	156,659	0.55	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	17,922	0.81	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-4,770		-2.19	Reservoir
Total Monitored Area		310,534	100.0%	169,811	0.55		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

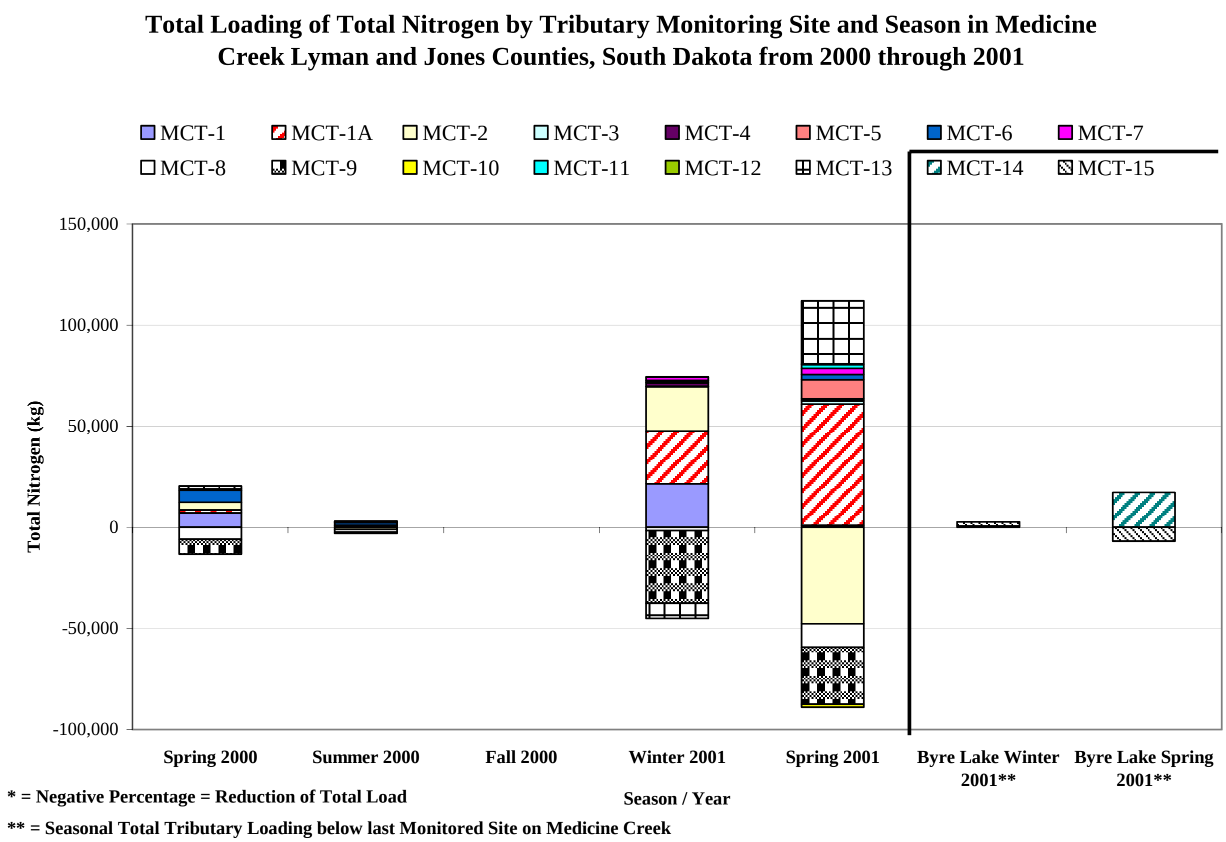


Figure 68. Seasonal total nitrogen loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Five sub-watersheds in Medicine Creek had overall load reductions in total nitrogen during the project period, MCT-2, MCT-8, MCT-9 MCT-10 and MCT-15. Three of the five annual load reductions by sub-watershed occurred at Fate Dam MCT-8 (-5.54 kg/acre), Brakke Dam MCT-10 (-1.30 kg/acre) and Byre Lake MCT-15 (-2.19 kg/acre), where phytoplankton, hydrophytes and bacteria can convert, reduce and assimilate inorganic nitrogen (ammonia and nitrate) into other forms and/or adsorption onto particles and subsequent settling may occur (Table 32). Total nitrogen load reduction at mainstem monitoring sites (MCT-2, MCT-9) were attributed to dense hydrophytes at MCT-2 and algae dominated ponded water at MCT-9, increasing the potential for total nitrogen reduction and uptake by aquatic plants or particle sorption and subsequent settling reducing various nitrogen species.

Total Phosphorus

Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake and utilization. Phosphorus sources in the Medicine Creek watershed can be natural from geology and soil, from decaying organic matter, waste from septic tanks or agricultural runoff.

Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan, 1995). Sampling data from Medicine Creek confirms this hypothesis with a good relationship between TSS and phosphorus (overall R^2 = 0.7259). These nutrients are also retained and released on stream banks and floodplains within the watershed. Phosphorus will remain in the stream sediments unless released by increased stage (water level), discharge or current. Re-suspending phosphorus and other nutrients associated with sediment into the water column (stream) should show increased concentrations during rain events (increased stage and flow). Reduced flows and discharge may deposit phosphorus and other nutrients associated with sediment on the stream banks and floodplains of Medicine Creek. Rain events increase flows and re-suspend sediment and phosphorus stored in the floodplain and stream banks. These concentrations combine with event-based concentrations to increase overall nutrient loading, producing peak concentrations of total phosphorus and total nitrogen in Medicine Creek.

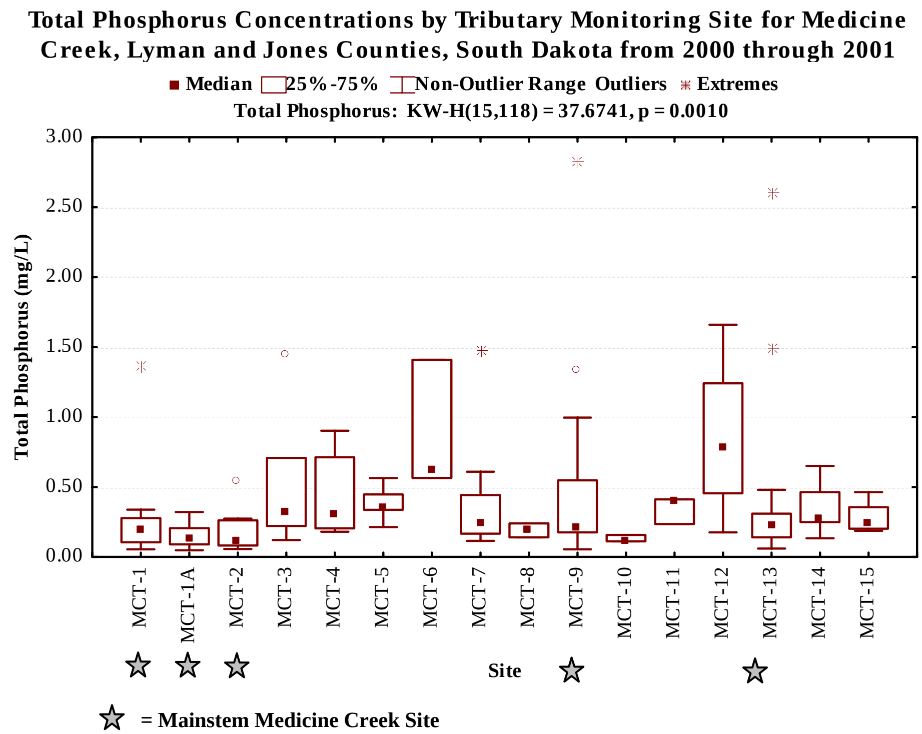


Figure 69. Total phosphorus concentrations and estimated loads to Medicine Creek and Medicine Creek from Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Total phosphorus concentrations and loading from Nail, Brakke and Grouse Creeks affect in-lake total phosphorus concentrations in Fate Dam, Brakke Dam and Byre Lake, respectively. Increased in-lake total phosphorus concentrations increase the Trophic State Index (TSI) and eutrophication processes shifting the total nitrogen to total phosphorus ratio from phosphorus limited (ideal) to nitrogen limited (excess phosphorus) and may cause algal blooms.

The median total phosphorus concentration for Medicine Creek was 0.229 mg/L (average 0. 383 mg/L) during the project. The maximum concentration of total phosphorus was 2.820 mg/L collected on April 25, 2001 at MCT-9 (mainstem Medicine Creek) and a minimum concentration of 0.048 mg/L at MCT-1A (North fork of Medicine Creek outlet) on May 13, 2001 (Appendix D). Site by site comparison of total phosphorus concentrations indicated that most median concentrations in mainstem Medicine Creek were below 0.250 mg/L while median total phosphorus concentrations in Stony Butte (MCT-4 and MCT-7) north of Presho, Nail Creek above Fate Dam (MCT-5 and MCT-6), Brakke Creek above Brakke Dam (MCT-11 and MCT-12) and Grouse Creek above and below Byre Lake (MCT-14 and MCT-15) were above 0.250 mg/L (Figure 69).

Total phosphorus concentrations originating in Medicine Creek eventually affect phosphorus concentrations on the Missouri River in Lake Sharpe. With median total phosphorus concentrations in Medicine Creek of 0.229 mg/L (average 0. 383 mg/L) and median total phosphorus concentrations in Lake Sharpe 0.036 mg/L (average 0. 036 mg/L), overall total phosphorus loading from Medicine Creek may eventually increase eutrophication in Lake Sharpe

Total phosphorus concentrations were significantly different between monitoring sites (Figure 69 and Table 4); however, not significant enough (p=0.0010) for detecting differences using mean separation procedures (Appendix B, Table B-18).

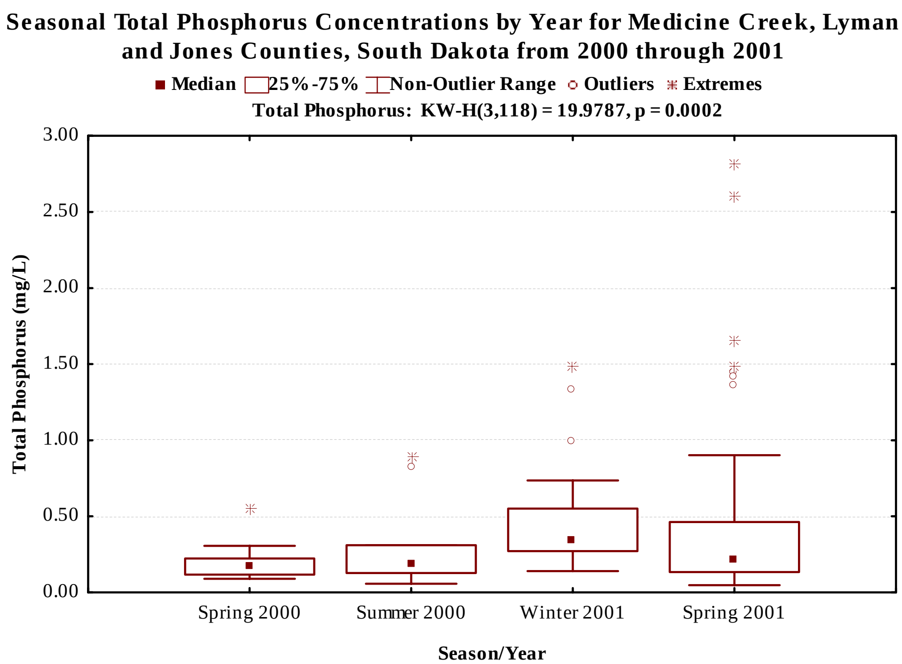


Figure 70. Seasonal median, quartile and range for total phosphorus concentrations by tributary monitoring site for Nail Creek, Lyman County, South Dakota from 2000 through 2001.

Total phosphorus concentrations were significantly different between sampling seasons (p=0.0002) with concentrations collected in the winter of 2001 significantly higher than the spring of 2000 and 2001 (Figure 70). Mainstem Medicine Creek total phosphorus concentrations were significantly lower (p=0.0000) than concentrations in upland tributaries to Medicine Creek (Figure 71). Total phosphorus was one of only two parameters that had significantly higher concentrations in the tributaries to Medicine Creek than in mainstem Medicine Creek. This may be due to increased agricultural runoff from cropped ground on the upland portions of the watershed into tributaries to Medicine Creek.

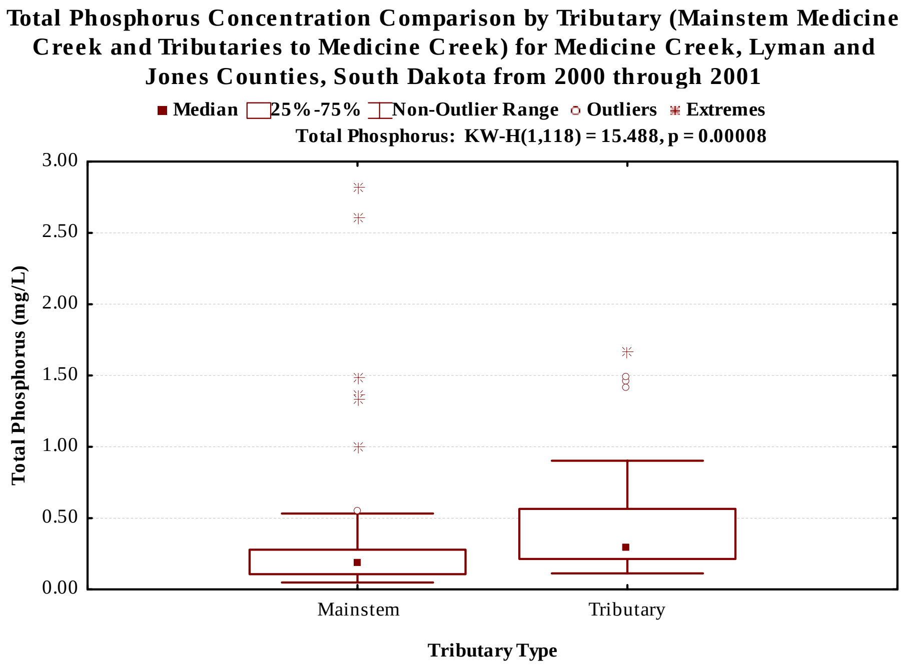


Figure 71. Total phosphorus concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total phosphorus loading by site was highest at site MCT-13 (35,401 kg) comprising 62.1 percent of the total phosphorus load in Medicine Creek and 15.1 percent of the hydrologic load (Table 33). Tributary total phosphorus loading by season was highest in the spring of 2001 for Medicine Creek and Byre Lake watersheds (Figure 72). Overall total phosphorus loading between sampling sites were statistically similar (p=0.0606) in the Medicine Creek watershed (Table 4 and Appendix B, Table B-31). Sub-watershed export coefficients (kilograms/acre) were highest in the MCT-13 sub-watershed (0.80 kg/acre) followed by MCT-9 (0.51 kg/acre) on mainstem Medicine Creek and MCT-14 (Grouse Creek above Byre Lake) at 0.43 kg/acre (Table 33).

Table 33. Total phosphorus loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Phosphorus Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	8,637	0.16	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	1,240	0.04	-	
Medicine Creek	**MCT-2**	22,455	1.3%	-8,170	-	-0.36	Extremely Vegetated Reach
Stony Butte Creek	**MCT-3**	33,254	6.1%	1,876	0.06	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	796	0.03	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	-775	-	-0.07	Extremely Vegetated Reach
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	15,826	0.51	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	835	0.10	-	
Nail Creek	**MCT-6**	7,451	8.5%	1,370	0.18	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-2,291	-	-1.19	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	446	0.04	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	172	0.06	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-429	-	-0.47	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	35,401	0.80	-	
Gauged Watershed Total		**286,358**	100.0%	57,007	0.20	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	9,391	0.43	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-6,898		-3.16	Reservoir
Total Monitored Area		310,534	100.0%	59,501	0.19		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Five sub-watersheds in Medicine Creek had overall load reductions in total phosphorus during the project period, MCT-2, MCT-8, MCT-9 MCT-10 and MCT-15. Like most parameters annual load reductions occurred at Fate Dam MCT-8 (-1.19 kg/acre), Brakke Dam MCT-10 (-0.47 kg/acre) and Byre Lake MCT-15 (-3.16 kg/acre), where phytoplankton, hydrophytes and bacteria can convert, reduce and assimilate inorganic nitrogen (ammonia and nitrate) into other forms and/or adsorption to onto particles and subsequent settling may occur (Table 33). Total phosphorus load reduction at mainstem monitoring sites (MCT-2, MCT-9) was attributed to dense hydrophytes at MCT-2 and algae dominated ponded water with some hydrophytes at MCT-9, increasing the potential for total phosphorus reduction and uptake by aquatic plants or particle sorption and subsequent settling reducing total phosphorus concentrations and overall phosphorus loading.

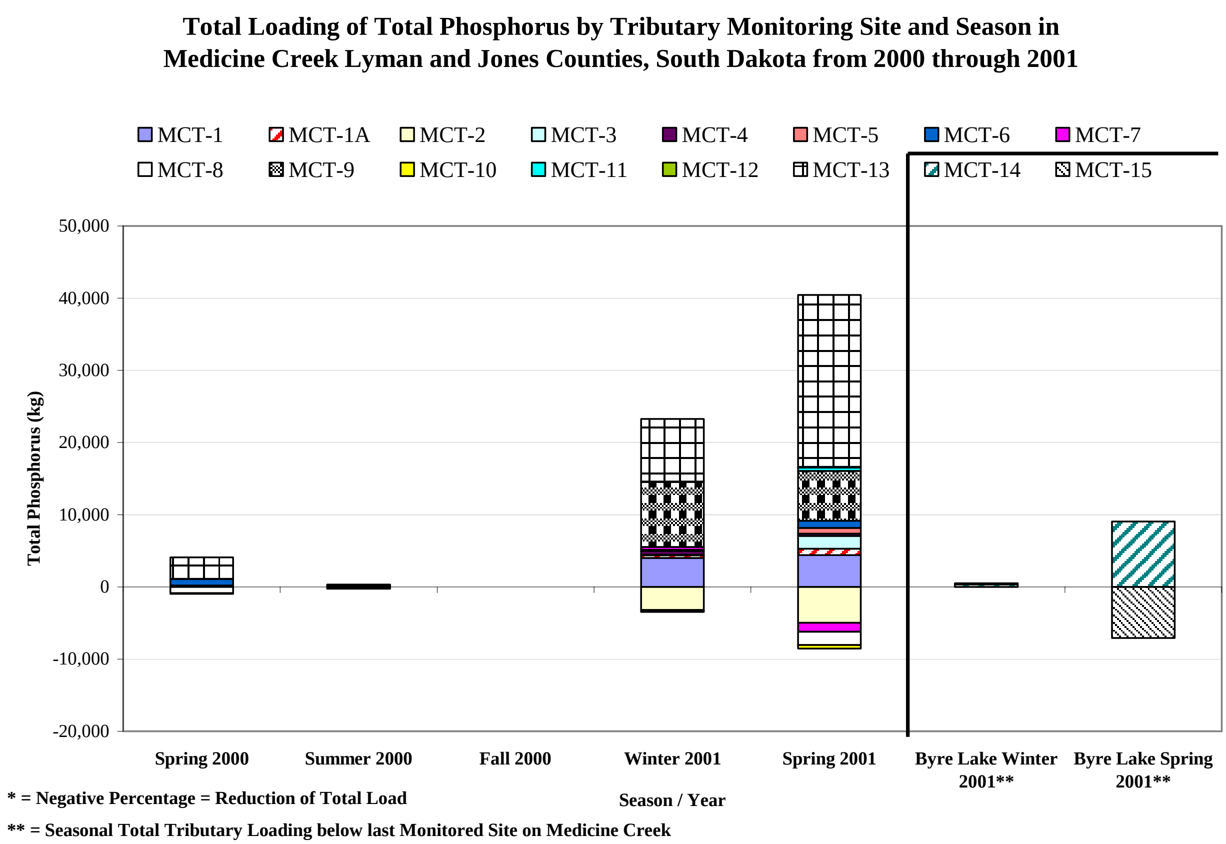


Figure 72. Seasonal total phosphorus loading by tributary monitoring site in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

As mentioned previously, total phosphorus concentrations in Nail, Brakke and Grouse Creek modify in-lake total phosphorus concentrations increasing the chance for algal blooms. Algae/periphyton only needs 0.02 mg/L of phosphorus to produce algal blooms in lakes (Wetzel, 2001). Data indicate that average total phosphorus concentrations from streams affecting lakes in the Medicine Creek watershed exceeded this threshold, with Nail Creek exceeding 21.9 times (Smith, 2004a); Brakke Creek exceeding 20.0 times (Smith 2004) and Grouse Creek exceeding

20.9 times (Smith 2003) the phosphorus needed to produce algal blooms Fate Dam; Brakke Dam and Byre Lake.

Reductions in total phosphorus loads are needed especially in Fate Dam, Brakke Dam and Byre Lake watershed and in Medicine Creek to maintain phosphorus-limitation throughout the year and improve TSI reductions in all three lakes and Medicine Creek which may eventually affect the Missouri River at Lake Sharpe. Alterations should be implemented in existing management practices to improve current conditions in these watersheds and Medicine Creek.

Decreasing total phosphorus inputs from Nail Creek, Brakke Creek and Grouse Creek should improve (lower) TSI values in reducing total phosphorus will decrease algal turbidity, which should increase Secchi transparency and decrease Secchi TSI values. Reducing phosphorus input should lower in-lake phosphorus concentrations and phosphorus TSI values. Reduced phosphorus concentrations may reduce available phosphorus for algae growth and uptake, which could lower algal densities that in turn decreases chlorophyll-*a* concentrations, reducing chlorophyll-*a* TSI values. Reductions in phosphorus over time should reverse increased TSI values observed in lakes in the Medicine Creek watershed. Every effort should be made to reduce total phosphorus loads to meet site specific TMDL goals for Fate Dam, Brakke Dam and Byre Lake watersheds.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on suspended materials (both organic and inorganic) if present in the water column and if not already saturated with phosphorus.

The median total dissolved phosphorus concentration for Medicine Creek was 0.117 mg/L (average 0.160 mg/L). The maximum concentration of total dissolved phosphorus was collected on April 25, 2001 at MCT-12 was 1.320 mg/L (east inlet to Brakke Dam) and a minimum of 0.002 mg/L at MCT-1A (North Fork of Medicine Creek) on May 31, 2000 (Appendix D). Total dissolved phosphorus concentrations were significantly different (p=0.0000) between monitoring sites (Table 4) with total dissolved phosphorus concentrations at MCT-1A significantly lower the MCT-4 on Stony Butte Creek, MCT-5 on upper Nail Creek and MCT-14 on Grouse Creek (Figure 73 and Appendix B, Table B-19). During this study, the percentage of total dissolved phosphorus to total phosphorus ranged from 2.2 percent to 96.6 percent in the spring of 2000 and averaged 41.7 percent over the project. Seasonally, total dissolved phosphorus concentrations were elevated in the winter of 2001 with 0.617 mg/L at MCT-12 (Table 16).

Total dissolved phosphorus concentrations were significantly different between sampling season (p=0.0000) with concentrations collected in the winter of 2001 significantly higher than the spring and summer of 2000 and the spring of 2001 while concentrations in the spring of 2000 were significantly lower than winter and spring of 2001 (Figure 74). Tributary Medicine Creek total dissolved phosphorus concentrations were statistically higher (p=0.0000) than concentrations mainstem Medicine Creek (Figure 75). Besides total phosphorus, total dissolved phosphorus was the only other parameter that had significantly higher concentrations in the tributaries to Medicine Creek than in mainstem Medicine Creek. Similar to total phosphorus, increased total dissolved phosphorus concentrations may be due to agricultural runoff from cropped ground on the upland portions of the watershed into tributaries to Medicine Creek.

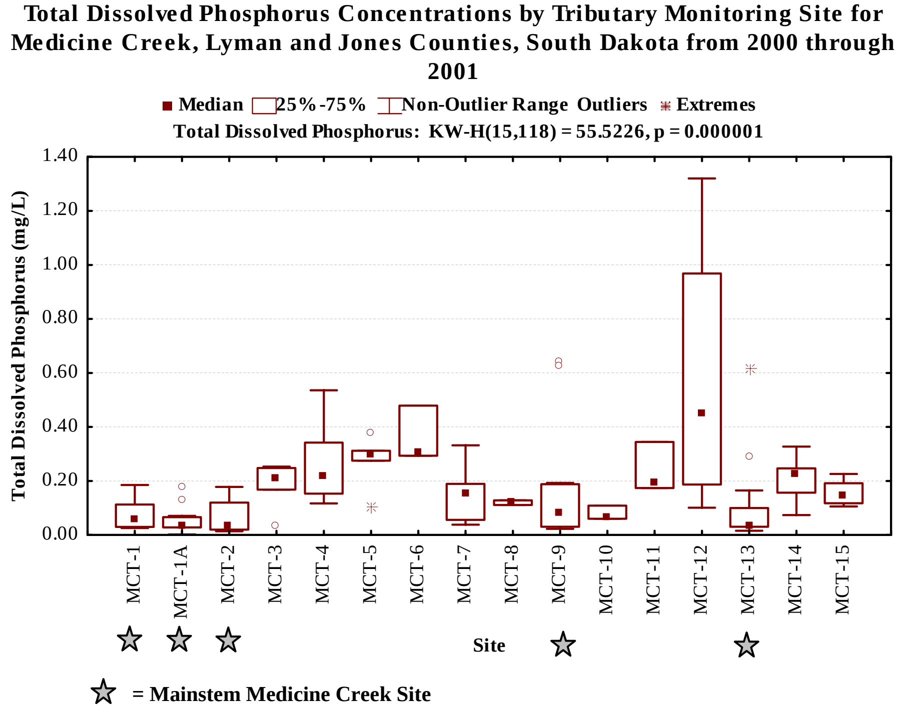


Figure 73. Total dissolved phosphorus concentrations by tributary monitoring site for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

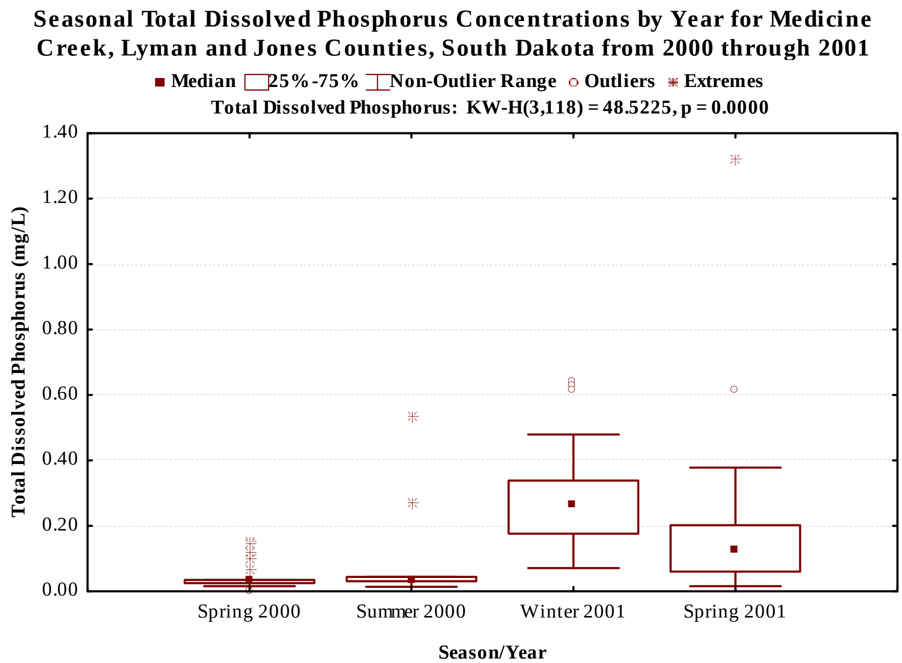


Figure 74. Seasonal total dissolved phosphorus concentrations for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

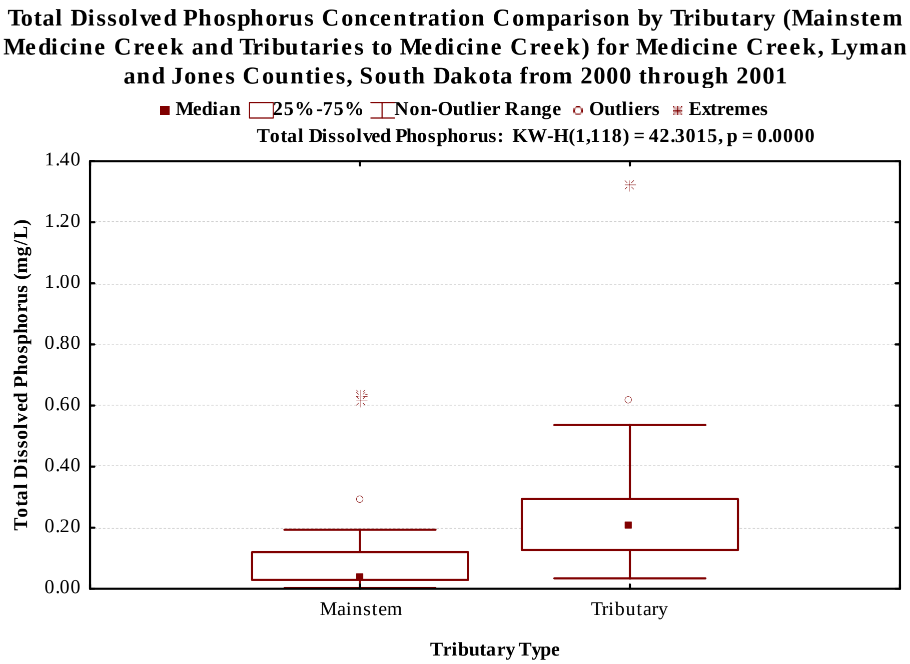


Figure 75. Total dissolved phosphorus concentration comparison by tributary (mainstem Medicine Creek and tributaries to Medicine Creek) for Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Table 34. Total dissolved phosphorus loading per year by site for Medicine Creek watershed and other monitored tributaries, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Total Dissolved Phosphorus Sub -watershed	Station	Gauged Watershed Acreage (Acres)	Percent Hydrologic Load (%)	Kilograms by site (kg)	Export Coefficient (kg/acre)	Stream Channel Reduction Potential (kg/acre)	Probable Scenario for Load Reduction
Upper Medicine Creek	**MCT-1**	55,556	34.4%	475	0.01	-	
North Fork of Medicine Creek	**MCT-1A**	32,106	18.7%	391	0.01	-	
Medicine Creek	**MCT-2**	22,455	1.3%	63	0.003	-	
Stony Butte Creek	**MCT-3**	33,254	6.1%	315	0.01	-	
Stony Butte Creek	**MCT-4**	22,797	5.3%	396	0.02	-	
Stony Butte Creek (North of Presho)	**MCT-7**	11,914	1.2%	235	0.02	-	
Medicine Creek (East of Presho)	**MCT-9**	31,200	0.2%	7,488	0.24	-	
Upper Nail Creek	**MCT-5**	7,975	7.1%	562	0.07	-	
Nail Creek	**MCT-6**	7,451	8.5%	32	0.00	-	
Fate Dam (Nail Creek near Dam Outlet)	**MCT-8**	1,932	13.9%	-745	-	-0.39	Reservoir
Brakke Creek (West Tributary)	**MCT-11**	11,678	6.0%	292	0.03	-	
Brakke Creek (East Tributary)	**MCT-12**	3,026	0.6%	136	0.05	-	
Brakke Dam (Brakke Creek near Dam Outlet)	**MCT-10**	917	3.7%	-282	-	-0.31	Reservoir
Medicine Creek (at Kennebec)	**MCT-13**	44,097	15.1%	1,778	0.04	-	
Gauged Watershed Total		**286,358**	100.0%	12,090	0.04	-	
Byre Lake Watershed							
Upper Grouse Creek	**MCT-14**	21,993	24.3%	9,391	0.43	-	
Byre Lake (Grouse Creek near Dam Outlet)	**MCT-15**	2,183	19.4%	-6,898		-3.16	Reservoir
Total Monitored Area		310,534	100.0%	13,321	0.04		
Ungauged Area		79,538					
Total Watershed Area		**390,072**					

Orange Highlighted = Tributary sites directly affecting Mainstem Medicine Creek

Blue Highlighted = Mainstem Medicine Creek

Total dissolved phosphorus loading by site was highest at site MCT-9 (7,488 kg) comprising 61.9 percent of the total dissolved phosphorus load in Medicine Creek and only 0.2 percent of the hydrologic load (Table 34). Tributary total dissolved phosphorus loading by season was highest in the spring of 2001 for Medicine Creek and Byre Lake watersheds (Figure 76). Overall total dissolved phosphorus loading between sampling sites were statistically similar (p=0.1805) in the Medicine Creek watershed (Table 4 and Appendix B, Table B-32). Sub-watershed export coefficients (kilograms/acre) were highest in MCT-14 (Grouse Creek above Byre Lake) at 0.43 kg/acre followed by MCT-9 sub-watershed on mainstem Medicine Creek (0.24 kg/acre) (Table 34).

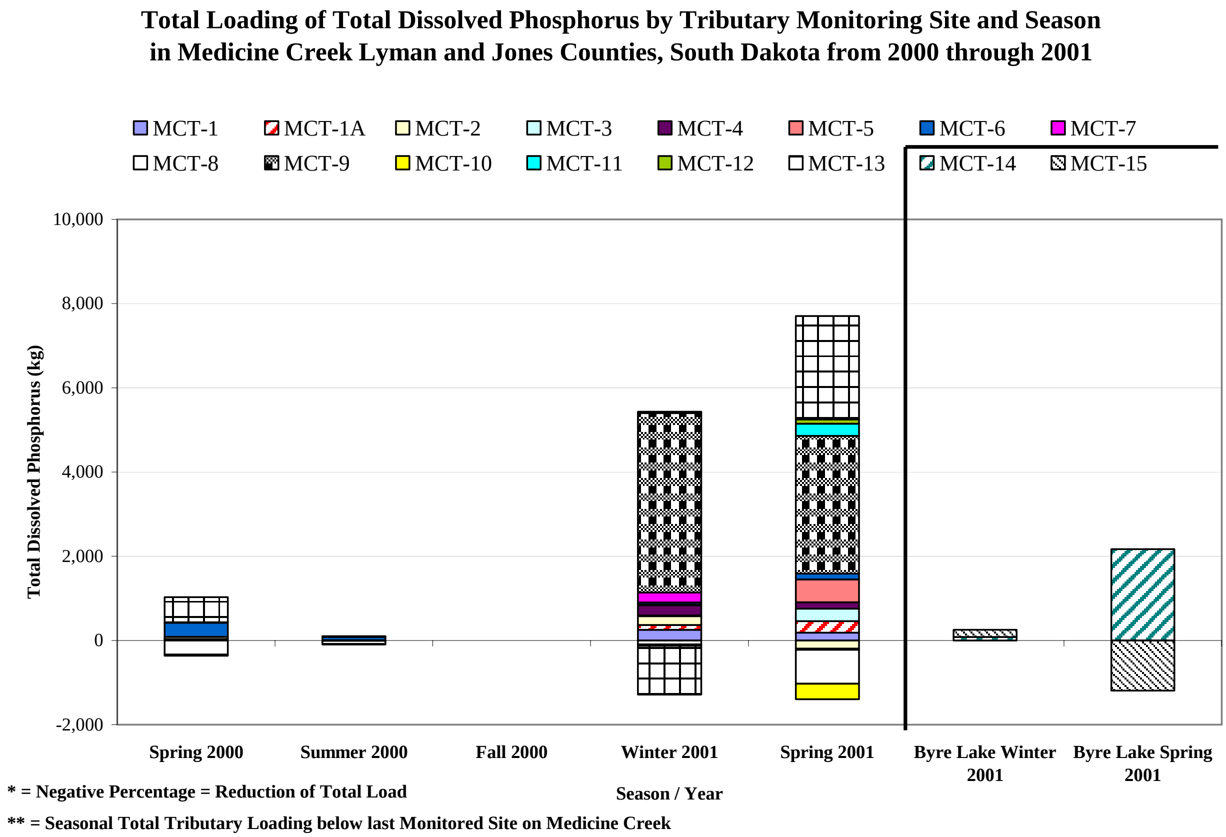


Figure 76. Seasonal total dissolved phosphorus loading in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Only three sub-watersheds in Medicine Creek had overall load reductions in total dissolved phosphorus during the project period, MCT-8, MCT-10 and MCT-15. All annual load reductions occurred below Fate Dam MCT-8 (-0.39 kg/acre), Brakke Dam MCT-10 (-0.31 kg/acre) and Byre Lake MCT-15 (-3.16 kg/acre), where phytoplankton, hydrophytes and bacteria can readily assimilate total dissolved phosphorus for growth (Table 33).

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of waste and presence of pathogens in a waterbody. Many outside factors can influence the concentration of fecal coliform. Like most bacteria, fecal coliform bacteria are sensitive to ultraviolet light. Sunlight and transport time can affect fecal coliform bacteria in a predictable way that can be calculated that can lessen fecal coliform concentrations although nutrient concentrations remain high. As a rule, just because fecal bacteria concentrations are low or non-detectable, does not mean animal waste is not present in a waterbody. South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30. The fecal coliform standard of 2,000 colonies/100ml applies only to mainstem Medicine Creek sites MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13 and listed as limited contact water.

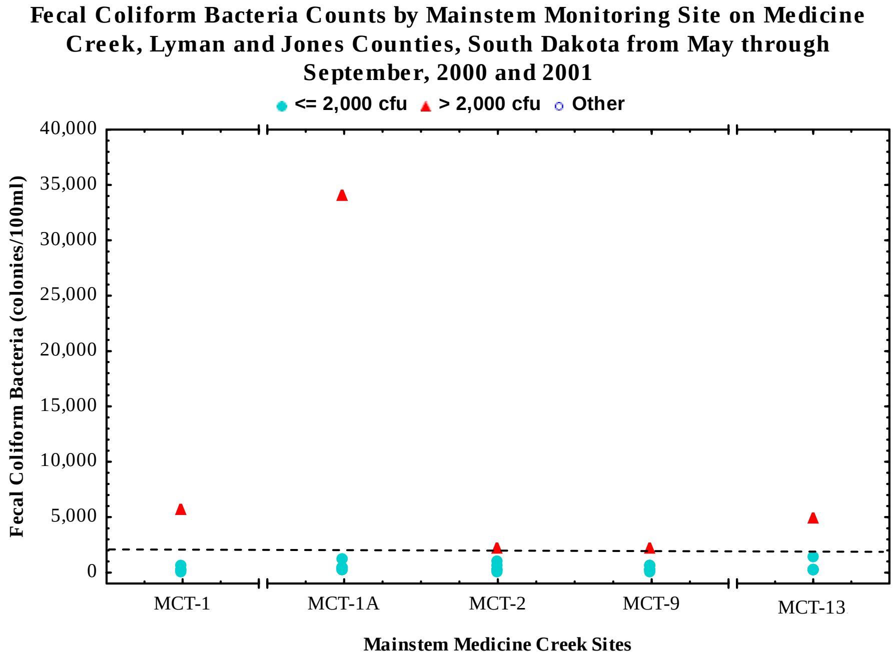


Figure 77. Fecal coliform concentrations (# colonies/100 ml) by mainstem monitoring site on Medicine Creek, Lyman and Jones Counties, South Dakota from May through September, 2000 and 2001.

The median fecal coliform count for all sites (MCT-1 through MCT-15) and dates was 80.0 colonies/100ml (average 2,613.3 colonies/100ml) with a maximum count of 150,000 colonies/100ml and a minimum count of 5 (½ the detection limit). Overall (using all dates), fecal coliform bacteria counts were not significantly different (p=0.1082) between Medicine Creek tributary monitoring sites (Table 4). Fecal coliform bacteria counts collected from May through September (dates standard applies) on mainstem Medicine Creek were also statistically similar (p=0.6038) during the project (Table 4). Descriptive statistics for mainstem Medicine Creek samples collected from May through September were as follows: a median count of 240 colonies/100ml (average 1,181 colonies/100ml) with a maximum of 34,000 colonies/100ml and a minimum of 5 (½ the detection limit).

Seven water quality violations in fecal coliform standards have been documented since 2000, five assessment samples and two WQM samples (Table 12). Assessment data indicates two violations occurred in June and three in July of 2000 during the assessment (Figure 78 and Table 12). All fecal coliform violations collected during the assessment were collected during low flow conditions (Table 12). Figure 78 indicates three of the five violations occurred during the summer sampling period which had the lowest flows. However, most fecal coliform samples collected in April of 2001 (outside the water quality standards window) were well above 2,000 colonies/100 ml and which were collected during high flow events. In April, fecal coliform counts ranged from 150,000 colonies/100 ml to 5 (½ the detection limit) with seven of the nine samples exceeding 2,000 colonies/100 ml were collected on mainstem Medicine Creek monitoring sites. Based on current data, fecal coliform is considered a problem requiring development of a fecal coliform TMDL for mainstem Medicine Creek. Fecal coliform bacteria is also identified as a parameter of concern in Lower Medicine Creek on the Lower Brule Sioux Reservation (Tetra Tech 2004 and Tetra Tech 2005).

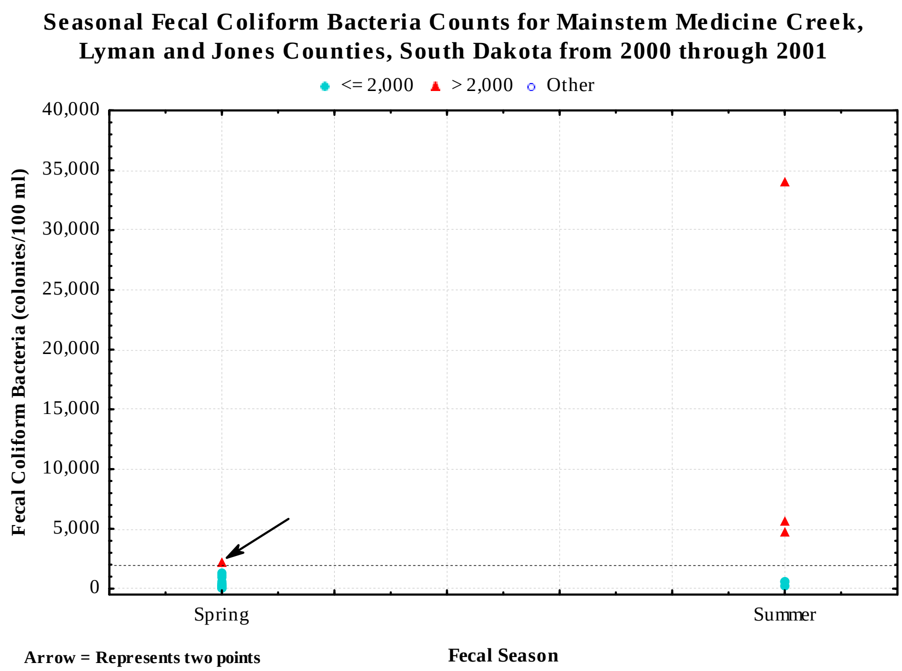


Figure 78. Seasonal fecal coliform concentrations in Medicine Creek, Lyman and Jones Counties, South Dakota from May through September, 2000 and 2001.

*Escherichia coli***,** *E. coli*, is a species of fecal coliform bacteria that lives in the intestines of humans and other warm-blooded animals and in their waste. EPA recommends *E. coli* bacteria as the best indicator of health risk from water contact in recreational waters. SD DENR Surface Water Quality Program (SWQP) is currently in the initial stages of developing surface water quality standards for *E. coli* bacteria in recreational waters (immersion recreation and limited contact recreation waters). SWQP has developed preliminary values for surface water quality standards for *E. coli* in limited contact recreation waters (beneficial use category (8)) from May 1 through September 30. The preliminary geometric mean based on a minimum of five samples collected during separate 24-hour periods for any 30-day period is $\leq$ 680 *E. coli* colonies/100ml and $\leq$ 1,178 *E. coli* colonies/100ml for any one sample. Because of *E. coli* standard development, *E. coli* samples were collected during the 2001 sampling year to monitor concentrations in mainstem Medicine Creek.

Based on samples collected for this project, *E. coli* counts (colonies/100ml) in mainstem Medicine Creek were below tentative water quality standards for *E. coli* in limited contact recreational waters (Figure 79). The median *E. coli* count for all sites on mainstem Medicine Creek from May through September was 153 colonies/100ml (average 169.8 colonies/100ml) with a maximum count of 308 colonies/100ml and a minimum count of 108 colonies/100ml.

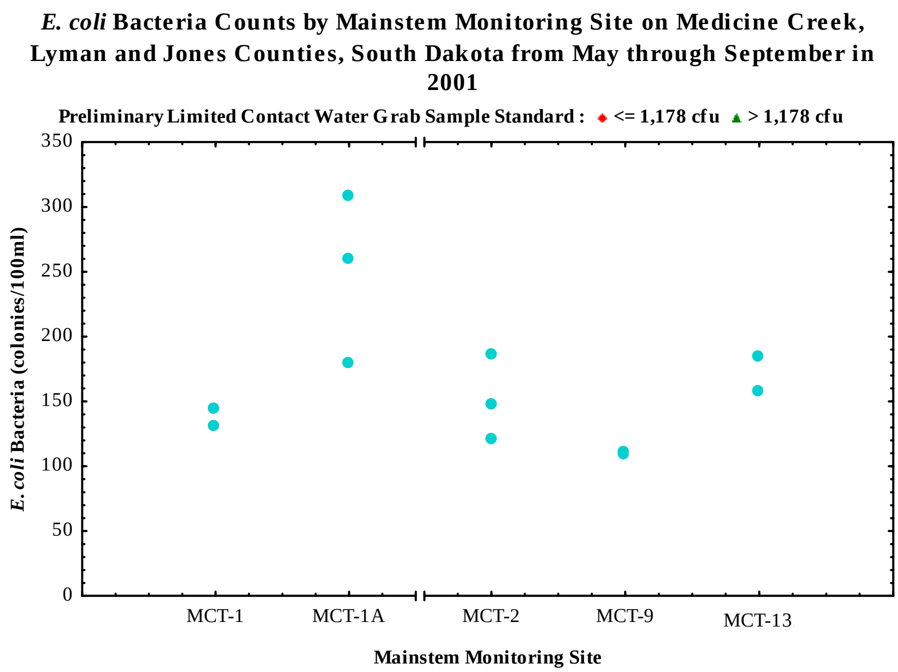


Figure 79. *E. coli* Bacteria Counts by Mainstem Monitoring Sites on Medicine Creek, Lyman and Jones Counties, South Dakota from May through September in 2001.

Based on 2001 data, Medicine Creek would meet a beneficial use based standard for *E. coli*; however, more data will need to be collected to determine the actual support status.

When comparing all *E. coli* bacteria collected during the project (all sampling sites from March through May 2001) five *E. coli* samples exceeded the preliminary 1,178 colonies/100ml standard. All five samples were collected in April of 2001 from four of the five mainstem monitoring sites in Medicine Creek (Figure 80). These data support the conclusion that at times coliform bacteria may be a concern in mainstem Medicine Creek.

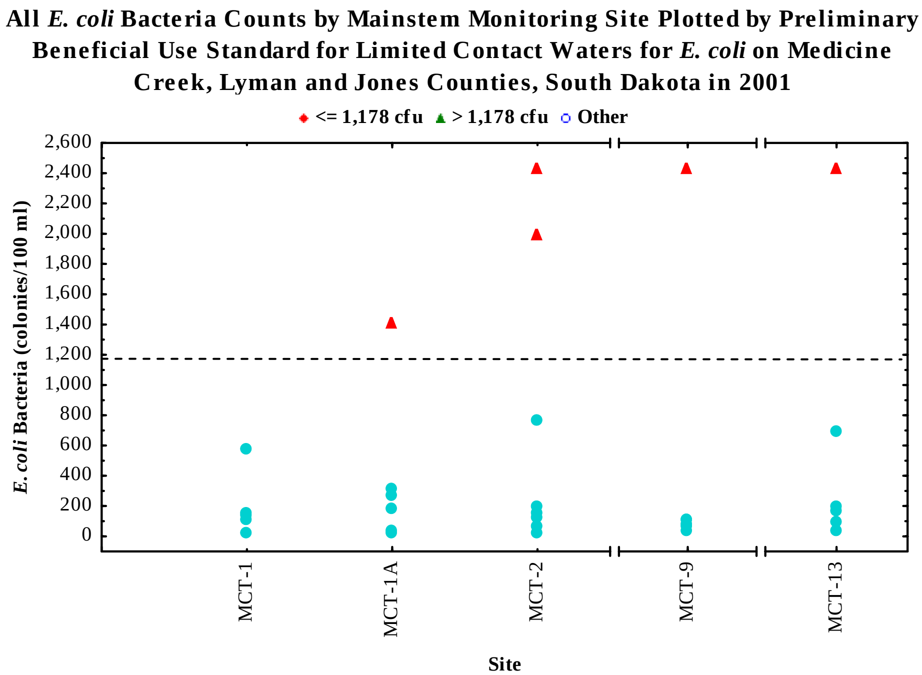


Figure 80. ***E. coli*** **Bacteria Counts on Mainstem Monitoring Sites for all dates (March through May 2001) on Medicine Creek, Lyman and Jones Counties, South Dakota.**

Although not listed in the *2004 South Dakota Integrated Report for Surface Water Quality Assessment* as impaired for fecal coliform, data show that 12.1 percent of all fecal coliform samples collected from May through September in Medicine Creek violated assigned surface water quality standards for fecal coliform (Table 12). TMDL listing criteria for South Dakota waters are if more than 10 percent of the samples (20 sample minimum) exceed the water quality standard the site is impaired and requires a TMDL (SD DENR, 2004). Fecal coliform violations in Medicine Creek exceeded the TMDL listing criteria; because of this, Medicine Creek will be listed in the 2006 Integrated Report as violating fecal coliform standards based on the limited contact water beneficial use listing. Therefore, a TMDL was developed for fecal coliform to reduce fecal coliform concentrations and improve water quality in Medicine Creek. Implementing modeled BMPs in critical feeding/wintering areas of the Medicine Creek watershed will reduce fecal coliform concentrations towards meeting the TMDL goal.

TMDL development for fecal coliform consisted of calculating yearly WLAs (Waste Load Allocations) in conjunction with SD DENR SWQP (Surface Water Quality Program) for all point sources that potentially discharge to mainstem Medicine Creek, model/estimate attainable fecal coliform load reductions from the watershed using assessment data and the Margin-Of-Safety (MOS) was considered implicit in that all LA (Load Allocations) were calculated using conservative reduction estimates. TMDL development followed EPA protocols for pathogen TMDLs (US EPA, 2001). Attainable fecal coliform load reduction percentages were estimated using AnnAGNPS data to estimate the total number of animals (horses, sheep, goats and cattle) in the watershed to calculate the appropriate load reduction for fecal coliform and determine LA for Medicine Creek. AnnAGNPS (feedlot/feeding area module) and SD DENR feedlot model were also used to determine feeding area locations (proximity to tributaries) and determine feedlot/feeding area rating numbers for reduction modeling and prioritize future BMPs.

To calculate the appropriate fecal coliform load reduction, the assessment fecal coliform violation percentage (approximately 16.0 percent) was used to calculate the reduction needed in average delivered waste load per animal (estimate the waste from the number of animals to reduce in order to meet the required load reduction based on the delivered fecal coliform load per animal ($4.72x10^9$ cfu/100 ml/animal)) to meet the fecal coliform TMDL.

The WLA (Waste Load Allocation) was calculated using the fecal coliform standard for limited contact waters (2,000 cfu/100 ml) and potential discharge from each facility provided by SD DENR SWQP. WLA was calculated using conservative discharge calculations and accounted for increased rainfall events and future municipal growth. The wastewater ponds at Presho are approximately 23.8 stream kilometers (14.8 stream miles) upstream from Kennebec, fecal coliform originating from the Presho facility and traveling downstream to Kennebec would be exposed to mixing and increased exposure to ultraviolet light resulting in fecal decay. To account for this, the exponential decay rate was used to calculate fecal coliform decay based on a constant, velocity and distance traveled. The formula used to calculate fecal coliform decay is provided in Equation 4.

Equation 4. Exponential decay rate for fecal coliform.

$$C_f = C_o \ x \ e^{\left(\frac{-K/D}{Q}\right)}$$

Where: **C_f = Fecal coliform corrected for decay**
C_o = Fecal coliform (original concentration)
-K = Decay coefficient (non-sterile river water)
D = Distance along axis of flow and
Q= Average flow velocity

Equation 5. Fecal coliform decay for Medicine Creek (MCT-13)

$$2{,}000\frac{cfu}{100\,ml} \ x \ e^{(-0.51/day\,x\,14.8\,miles)/238.9\,miles/day)} = 1{,}938\frac{cfu}{100\,ml}$$

Fecal coliform decay in Medicine Creek from Presho to Kennebec was estimated at 62 cfu/100 ml leaving 1,938 cfu/100 ml viable colonies at Kennebec (Equation 5). The adjusted fecal coliform concentration was used along with fecal coliform concentration at Kennebec to develop the WLA for Medicine Creek.

The load allocation for Medicine Creek was calculated using assessment water quality data. With the fecal coliform standard in effect from May through September (fecal season), the average assessment fecal coliform concentration during this period was calculated/estimated to be 1,811 colonies/100 ml (cfu/100 ml) based on 32 samples (Table 12). The total hydrologic load during the fecal season (May through September = 90,379,356 ft^3) was calculated using the

FLUX model. This information (the average concentration and total hydrologic load during the fecal season) was used to calculate the average load of fecal coliform over the fecal season using Equation 6.

Equation 6. Average fecal coliform load from May through September in mainstem Medicine Creek calculated using measured hydrologic load at MCT-13.

$$1{,}811\frac{cfu}{100\,ml}\,x\,\frac{10}{1L}\,x\,\frac{1L}{0.0353\,ft^3}\,x\,\frac{90{,}379{,}356\;ft^3}{fecal\,season}=4.64x10^{13}\,\frac{cfu}{fecal\,season}$$

Based on the fecal coliform violation rate, the average fecal coliform concentration needs to be reduced by 16 percent to meet the TMDL; however, with no realistic load reduction from the WLA, an additional load reduction will need to come from the LA to reach the assigned TMDL. Because the entire load reduction will have to come from the LA, an additional 2.3 percent reduction is needed in the LA (18.3 percent total load reduction) to reach an overall fecal coliform reduction that represents a 16 percent total load reduction. The average fecal coliform load needs to be reduced by an estimated 331 cfu/100 ml (from 1,811 cfu/100 ml to 1,480 cfu/100 ml) to meet the fecal coliform TMDL. This represents an 18.3 percent reduction in average fecal coliform concentrations from May 1 through September 30. 1,480 cfu/100 ml was used to determine the fecal coliform load per fecal season (Equation 7).

Equation 7. Average fecal coliform needed to realize an overall 16 percent reduction in fecal coliform loading and meet the TMDL.

$$1{,}480\frac{cfu}{100\,ml}\,x\,\frac{10}{1L}\,x\,\frac{1L}{0.0353\,ft^3}\,x\,\frac{90{,}379{,}356\;ft^3}{fecal\,season}=3.79x10^{13}\,\frac{cfu}{fecal\,season}$$

The average difference between the initial fecal load and the reduced fecal load ($8.47x10^{12}$ cfu/fecal season) was used to determine fecal coliform waste reduction. Fecal coliform waste from an estimated 1,793 animals needs to be reduced to meet the TMDL based on the average delivered fecal coliform loading per animal (Equation 8). This represents a 5.48 percent reduction in the total animals in the watershed (9,824 animals) producing an 18.3 percent reduction in the average delivered fecal coliform load. All load allocation calculations were calculated using extremely conservative reduction percentages translating to an implicit MOS.

Equation 8. Average number of animals to reduce delivered waste to meet the TMDL.

$$8.47x10^{12}\,\frac{cfu}{fecal\,season}\,x\,\frac{9{,}824\,animals\,in\,the\,watershed}{4.64x10^{13}\,delivered\,load\;\;fecal\,season}=waste\,reduction\;\;from\;1{,}793\,animals$$

The fecal coliform TMDL for Medicine Creek at MCT-13 is to reduce the calculated current fecal season load allocation to $3.79x10^{13}$ cfu/fecal season or approximately 18.3 percent producing a fecal coliform TMDL of $3.89x10^{13}$ cfu/fecal season (an approximate overall reduction of 16 percent) with an implicit MOS (Table 52). This TMDL ($3.89x10^{13}$ cfu/fecal season (May 1 through September 30)) translates into a 16 percent reduction in the violation rate for fecal coliform ($\leq$ 2,000 cfu/100 ml for any one grab sample) and should meet the fecal coliform standard for limited contact recreation waters.

Medicine Creek Total Nitrogen /Total Phosphorus Ratios (Limiting Nutrient)

Nutrients are inorganic materials necessary for life, the supply of which is potentially limiting to biological activity within lotic (stream) and lentic (lake) ecosystems. Lakes that have average concentrations of total phosphorus of 0.01 mg/L or less are considered oligotrophic, while lakes with more than 0.030 mg/L, usually eutrophic (Wetzel, 2001). The conventions of oligotrophic and eutrophic states do not have the same utility for running water that they do for lakes, nor is there evidence for a natural process of eutrophication corresponding to lake succession (Hynes, 1969). Studies from diverse regions of North America (Omernik, 1977, Stockner and Shortreed, 1978 and Pringle and Bowers, 1984) imply that phosphorus limitation is widespread in streams. It is apparent that variations in nutrient concentrations and nitrogen-to-phosphorus ratios have predictable consequences for algae/periphyton community structure and metabolism in running waters (Allan, 1995).

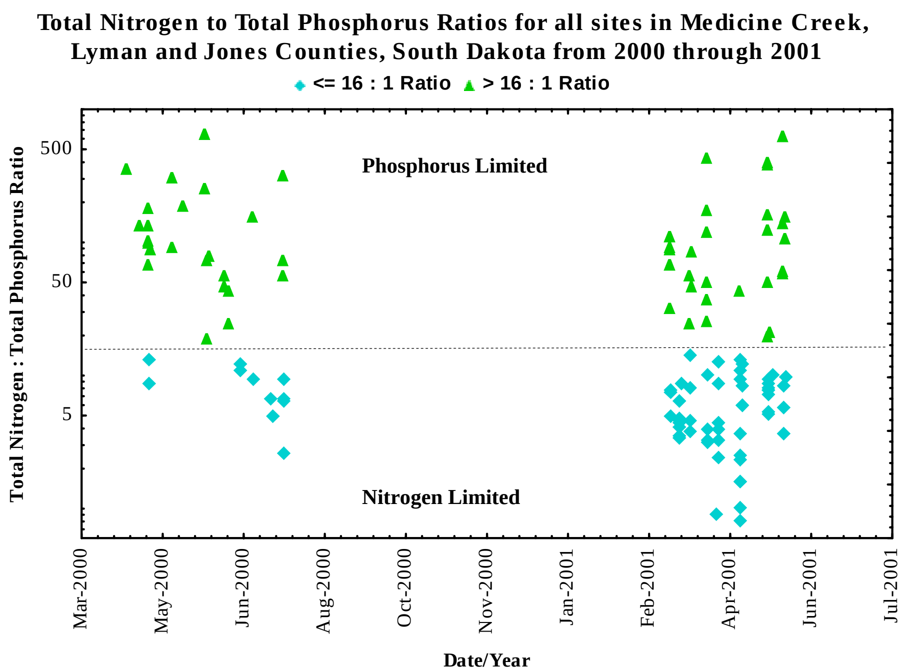


Figure 81. Total nitrogen-to-total phosphorus ratios based on tributary concentrations in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 and 2001.

Most estimates of the total nitrogen-to-total phosphorus ratio in freshwaters are above 16:1, based on the Redfield ratio (Redfield, et. al., 1963) and numerous bioassay experiments (Allan, 1995). This suggests that nitrogen is in surplus and phosphorus is in limited supply. The Environmental Protection Agency (EPA) has suggested total nitrogen-to-total phosphorus ratios for lakes of 10:1 as being the break for phosphorus limitation (US EPA, 1990). For tributary samples, a total nitrogen-to-total phosphorus ratio of 16:1 was used to determine phosphorus limitation.

Total nitrogen-to-total phosphorus ratios were calculated from all tributary monitoring sites (118 samples from 16 sites,) by date and by sampling site (Figure 81 and Figure 82, respectively). Seasonally, MCT-1A had the highest total nitrogen-to-total phosphorus ratios during the project, 2000 through 2001 (Table 14 through Table 17). Total nitrogen-to-total phosphorus ratios were statistically different (p=0.0000) between tributary monitoring sites (Table 4). In tributaries to Medicine Creek (upland tributaries), total nitrogen-to-total phosphorus ratios were considered nitrogen limited and phosphorus limited in mainstem Medicine Creek based on a 16:1 ratio (Figure 82). Phosphorus limitation was especially prevalent in the upper portion of the watershed (MCT-1, MCT-1A and MCT-2) and was attributed to naturally occurring nitrate-nitrite concentrations originating from the Pierre Shale formation with related soils and groundwater seeps.

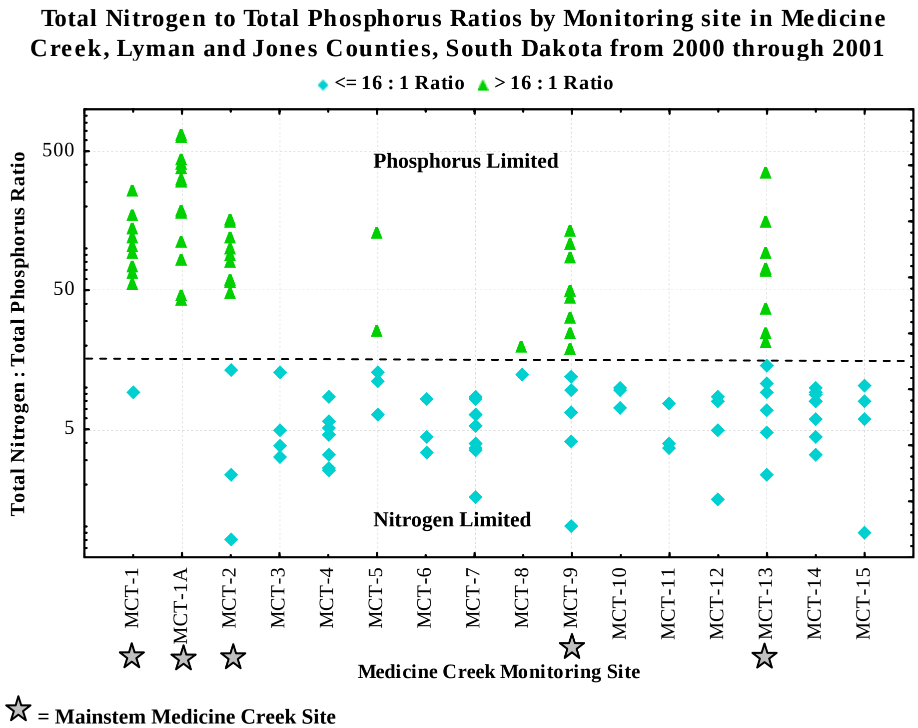


Figure 82. A comparison of total nitrogen to total phosphorus ratios (mg/L) by TMDL (lake) tributary in the Medicine Creek Watershed, Lyman County, South Dakota from 2000 through 2001.

3.2 Groundwater Monitoring

Two groundwater seep samples were collected and analyzed for TDS constituents and specific conductance values that influence surface water quality in Medicine Creek. Sampling results and discussion of groundwater seep samples can be found in the specific conductance (page 45) and total dissolved solids (page 64) portions of this report

3.3 Biological Monitoring

Benthic Macroinvertebrates

Biological data was collected over a 45-day period during late summer and early fall of 2001. Rock baskets were used to collect benthic macroinvertebrates during the designated index period. A description of the rock baskets and how they were deployed can be found in the Standard Operating Procedures, Volume II (SD DENR, 2005a). Macroinvertebrates were collected and shipped to a private consultant (Natural Resource Solutions) for identification and enumeration. A standard count of 300 organisms was used in the calculation of 45 metrics (Table 35).

Testing of Candidate Metrics

The benthic macroinvertebrate community can be characterized through a wide variety of metrics. Each metric detects differences in the benthic community. The goal of calculating an adequate number of metrics and comparing them across varying site conditions and/or river basins is to be able to identify which metrics do a better job at discriminating between site conditions.

A metric is a mathematical characterization of the aquatic macroinvertebrate community using the presence or absence of various genera/species of macroinvertebrates within a stream. Each group of insects (or lack thereof) can be used as indicators of the health of the aquatic community and serve as long-term indicators of the water quality within the stream or lake.

The 45 metrics shown in Table 35 were calculated for each of the individual rock baskets (three baskets per site. The three replicates (baskets at MCT-2, MCT-9 and MCT-13) determine which metrics had greater sensitivity for detecting differences between sampling sites in mainstem Medicine Creek. These 45 metrics were screened for their ability to detect changes between sampling sites (Table 35). All metrics fell into one of five general categories: taxonomic composition, taxonomic richness or abundance, feeding or trophic groups, life habit and degree of tolerance to stress in the environment.

Metrics were analyzed using a Kruskal-Wallis non-parametric test to determine metric values differed between sites (df=2, n=9). Table 36 shows metrics that exhibited the strongest differences between sampling sites (core metrics). Candidate (core) metrics were chosen from three main categories (Table 36 and Figure 83).

Table 35. Metrics Calculated for the Medicine Creek Watershed Assessment

Category	#	Metric	Expected Response to Increasing Disturbance
Abundance Measures	1	Corrected abundance	Variable
	2	EPT abundance[1]	Decrease
	3	total taxa	Decrease
Dominance Measures	4	% 1 dominant taxon	Increase
	5	% 2 dominant taxa	Increase
	6	% 3 dominant taxa	Increase
Richness Measures	7	Species richness	Decrease
	8	EPT richness	Decrease
	9	Ephemeroptera richness	Decrease
	10	Trichoptera richness	Decrease
Community Composition	11	% Ephemeroptera	Decrease
	12	% Trichoptera	Decrease
	13	% EPT	Decrease
	14	% Coleoptera	Decrease
	15	% Diptera	Increase
	16	% Baetidae	Increase
	17	% Chironomidae	Increase
	18	% Oligochaeta	Increase
	19	% Ephemerellidae	Decrease
	20	% Hydropsychidae	Increase
	21	% Odonata	Increase
	22	% Simuliidae	Increase
Functional Group Composition	23	% filterers	Increase
	24	% gatherers	Decrease
	25	% predators	Decrease
	26	% scrapers	Decrease
	27	% shredders	Decrease
	28	filterer richness	Decrease
	29	gatherer richness	Decrease
	30	predator richness	Decrease
	31	scraper richness	Decrease
	32	shredder richness	Decrease
Diversity/Evenness Measures	33	Shannon-Weaver H' (log 10)	Decrease
	34	Shannon-Weaver H' (log 2)	Decrease
	35	Shannon-Weaver H' (log e)	Decrease
	36	Hilsenhoff Biotic Index (HBI)	Increase
	37	Margalef's Richness	Decrease
	38	Metals Tolerance Index	Increase
	39	Pielou's J'	Decrease
	40	Simpson's Heterogeneity	Decrease
	41	Jaccard Similarity Index	Decrease
	42	Percent Similarity	Decrease
Habit Metrics	43	Long-lived taxa richness	Decrease
	44	Clinger richness	Decrease
	45	% tolerant taxa	Increase

[1]= EPT abundance was comprised of Ephemeroptera and Trichoptera.
Shaded metrics = Medicine Creek statistical differences between monitoring sites.

Table 36. Kruskal-Wallis analysis p-values for three core metrics from Medicine Creek

Metric	Differences between Sites((df=2, N=9) p-values <0.05)
EPT Abundance	0.034
Percent Coleoptera	0.027
No. Predator Species	0.048

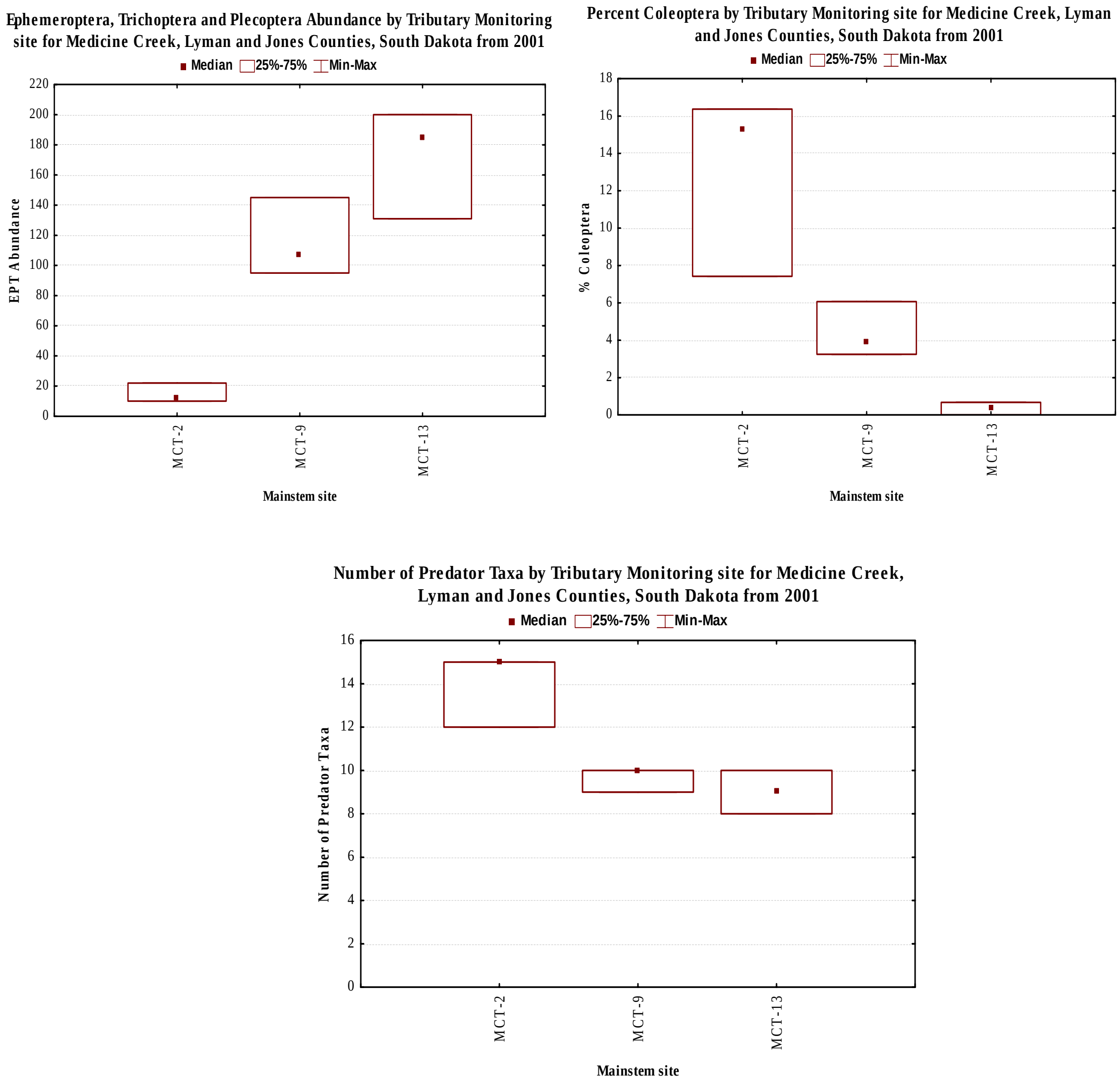


Figure 83. Core metrics for Medicine Creek based on October 2001 data.

Individual core metric values by monitoring site varied widely with much of the variation by category explained by in-stream habitat. The MCT-2 sampling reach has been channelized creating a highly vegetated depositional habitat thus anthropogenic alterations in the stream channel altered the habitat and ultimately the biological community response at this site. EPT abundance taxa (comprised of Ephemeroptera and Trichoptera) tend to be more abundant in erosional habitat; MCT-2 having had lower numbers of EPT taxa, while MCT-9 was more conducive to EPT taxa with slack water with some in-stream vegetation and some cobble habitat and MCT-13 with an erosional cobble habitat was most conducive to these species. Ephemeroptera taxa were comprised mostly of Caenis species, a relatively tolerant species with a Hilsenhoff Biotic Index (HBI) value (organic pollution tolerance value) of 7 on a scale of zero (intolerant) to ten (tolerant). Caenis species are relatively common in rivers and streams in central and eastern South Dakota. Percent Coleoptera was just the opposite decreasing from highly vegetated depositional habitat (MCT-2) upstream to erosional habitat with little in-stream debris (MCT-13) and/or vegetation (Figure 83). The number of predator species was highest in the depositional habitat at MCT-2 and were similar (lower) in erosional habitats at MCT-9 and MCT-13 (Figure 83). More biological data will need to be collected in the future to further expand and refine core metrics to calculate IBI values (Index of Biotic Integrity) and detect changes in the biological communities in Medicine Creek and ecoregion 43. A complete macroinvertebrate report prepared by Natural Resource Solutions, Brookings, South Dakota is provided in Appendix E.

3.4 Other Monitoring

Reservoir Sampling Summary for Reservoirs in Medicine Creek

Brakke Dam

Part of the Medicine Creek watershed assessment project incorporated the assessment of Brakke Dam and Brakke Creek. The Brakke Dam watershed drains an area of approximately 4,568.1 ha (11,288 acres) and enters Medicine Creek downstream of MCT-9 east of Presho, South Dakota. Medicine Creek tributary monitoring sites MCT-11 (western Brakke Dam inlet) and MCT-12 (eastern Brakke Dam inlet) were located above the lake and MCT-10 (Brakke Dam outlet) was located below Brakke Dam. Brakke Dam is a recreational lake of approximately 52.6 ha (130 acres) and has been impacted by periodic algal blooms. The following is a synopsis from the complete Brakke Dam/Brakke Creek Assessment Report and EPA approved TMDL (Smith 2004).

Brakke Creek Summary

Brakke Creek drains a watershed of approximately 4,568.1 ha (11,288 acres) and is impounded by Brakke Dam in Lyman County, South Dakota (Figure 2). Brakke Creek was monitored for tributary loading to Brakke Dam from April 2000 through May 2001. Approximately 1,461 acre-feet of water flowed into Brakke Dam from the gauged portion of the watershed (10,745 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Brakke Dam/Brakke Creek watershed was 0.12 acre-foot. Peak hydrologic load for the watershed occurred in the spring of 2001. Because of dry conditions in Lyman County, no runoff was recorded in the 2000 sampling season. Approximately 95.9 percent of the total hydrologic load delivered to Brakke Dam was delivered in the spring of 2001.

Brakke Creek was monitored using nineteen water quality parameters. In the Brakke Dam watershed, more than half of the parameters (57.9 percent) had the highest average concentrations for tributary sites in the spring of 2001. The remaining six water quality parameters (42.1 percent) had the highest average concentrations and/or values in the winter of 2001. Brakke Creek tributary samples did not exceed water quality standards during the project period.

South Dakota water quality standards for fecal coliform bacteria do not apply to Brakke Creek (designated beneficial uses, 9-Fish and wildlife propagation, recreation, and stock watering waters and 10-irrigation waters) however, during this study, one high fecal coliform count (29,000 colonies/100ml) collected in late April (MCT-12 on 4/25/01) was observed in the watershed (bacteria standards in effect from May 1 through September 30). Although not applicable, elevated fecal coliform counts are unhealthy when people come in contact with contaminated water. Runoff from land-applied manure, cattle or wildlife may be responsible for the sporadic high fecal concentrations.

Total phosphorus loading to Brakke Dam from Brakke Creek is 618 kg/yr; at a minimum, all modeled Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Brakke Dam. Based on site-specific standards for Brakke Dam, an 18.9 percent reduction in total phosphorus (approximately 117 kg/yr) is needed to fully support site specific beneficial use criteria and meet the total phosphorus TMDL of 501 kg/yr. AnnAGNPS modeling indicates an 18.9 percent reduction in total phosphorus load is attainable in the Brakke Dam watershed.

Sub-watersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on water quality modeling export coefficients, are presented by priority ranking in Table 37.

Table 37. Brakke Creek watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment modeling.

Parameter	Sub-watershed	Priority Ranking	Export Coefficient (kg/acre)	Delivered Load (kg)
Sediment	MCT-11	1	9.6	71,538
	MCT-12	2	3.4	11,118
Nitrogen	MCT-11	1	0.25	1,862
	MCT-12	2	0.11	357
Phosphorus	MCT-11	1	0.06	446
	MCT-12	2	0.05	172

Brakke Dam In-lake Summary

Brakke Dam is a 52.6 ha (130 acre) impoundment located in Lyman County, South Dakota and was included in the 1998 and the 2002 South Dakota's impaired waterbodies list and is listed in the State of South Dakota's 2004 Integrated Report (combined 305(B) and 303(d) reports) for increasing TSI trend (SD DENR, 1998; SD DENR, 2002 and SD DENR, 2004). Brakke Dam exceeded Ecoregion 43 targeted TSI values based on mean TSI and was in need of a TMDL. However, during this study, no in-lake surface water quality samples exceeded surface water quality standards.

Water quality data from this study identify Brakke Dam as partially supporting using assigned beneficial uses criteria based on current Ecoregion 43 criteria (mean TSI $\leq$ 55.00). However, current ecoregional (Ecoregion 43) target criteria appear not to fit Brakke Dam based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. An alternate site-specific (watershed-specific) evaluation criterion was proposed (fully supporting, mean TSI $\leq$ 65.00) and accepted by the Environmental Protection Agency (US EPA) for Brakke Dam. Currently, even with the new criterion, Brakke Dam still only partially supports site specific beneficial use criteria.

Current data indicate that reductions in total phosphorus are needed in both the watershed and in Brakke Dam to meet site-specific criteria based on AnnAGNPS modeled attainability. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Brakke Dam watershed. Decreasing tributary sediment, nitrogen and phosphorus inputs from Brakke Creek will improve (lower) Brakke Dam TSI values. Tributary reductions in these parameters will reduce Secchi, total phosphorus and chlorophyll-*a* TSI values and increase transparency (reduce algal and non-algal turbidity).

The site specific (watershed-specific) evaluation criteria for Brakke Dam (fully supporting, mean TSI $\leq$ 65.00) were based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability. This evaluation criterion was developed and calculated using measured loads and may not take into account long term annual load variation.

Brakke Dam TMDL

Based on site-specific criteria under current conditions, using adjusted chlorophyll-*a* values, Brakke Dam only partially supports beneficial uses (mean TSI=65.49) using this evaluation criteria. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Brakke Dam watershed. BMP based reduction criteria for Brakke Dam were estimated based on a 18.9 percent reduction in total phosphorus loads (117 kg/yr) to Brakke Dam resulting in a phosphorus TMDL of 501 kg/yr resulting in a mean TSI of 64.51.

The 18.9 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all phosphorus fertilized fields with moderate to low fertilizer rates (29.4 percent) reduced one level (moderate to low or low to none) or 5.2 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or 8.9 percent reduction; (3) applying conservation tillage to all priority-one and priority-two phosphorus critical cells (4-critical cells) or 0.3 percent and (4) converting tilled/cropped priority-one and priority-two phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or 4.5 percent. Combining all reductions the best estimated phosphorus reduction for Brakke Dam watershed is 18.9 percent.

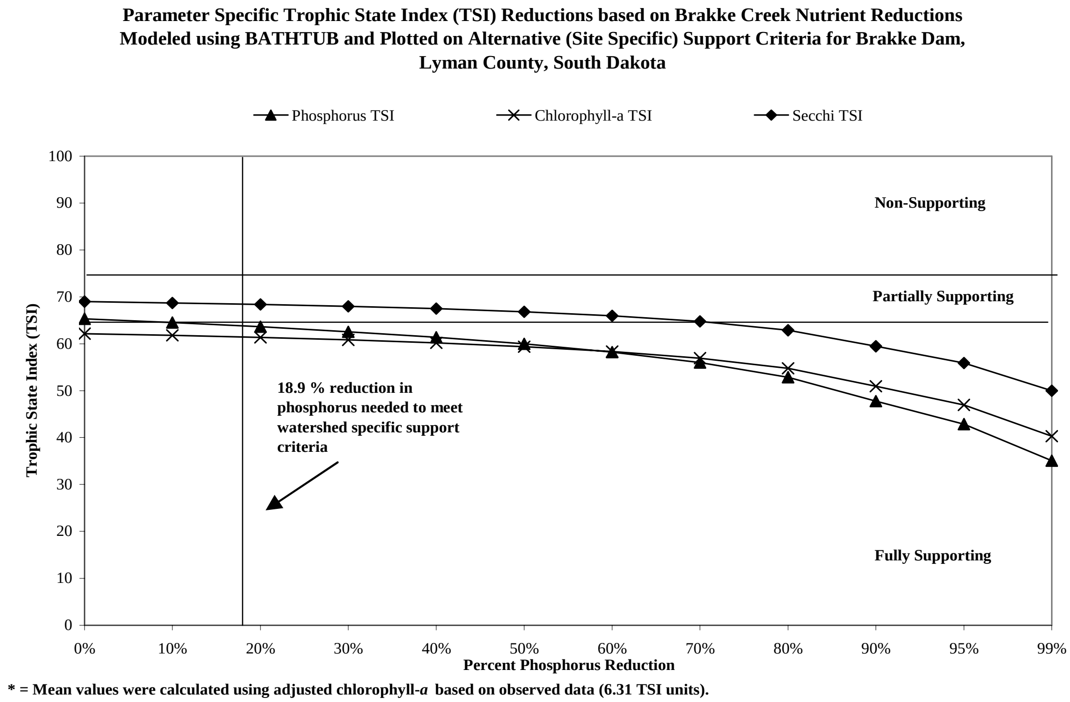


Figure 84. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Brakke Dam, Lyman County, South Dakota using 2000 and 2001 data.

Targeted reductions for specific parameters and mean TSI values were modeled through the BATHTUB reduction model. All reductions were modeled or calculated using water quality and/or AnnAGNPS data collected during this study. Modeled tributary and in-lake TSI reductions were based on best management practices, best professional judgment and conversations with the American Creek Conservation District (project sponsor). The Margin of Safety (MOS) for phosphorus is implicit. Implicit, in that, all modeled reduction estimations for tributary BMPs were calculated using extremely conservative reduction values/percentages (Brakke Dam Assessment Report, Appendix I). Any additional implemented BMP reductions were incorporated into the TMDL equation in the implicit margin of safety.

Based upon 2000 and 2001 modeled data, both phosphorus TSI (65.33) and Secchi TSI (68.97) values were partially supporting; however adjusted chlorophyll-*a* TSI values (62.17) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 84). SD DENR-recommended targets for specific TSI parameters for Brakke Dam were based on watershed-specific criteria and tributary BMP attainability. They were 63.72 for phosphorus, 61.40 for adjusted chlorophyll-*a* and 68.41 for Secchi visibility (Table 39). To reach these goals, tributary total phosphorus loads will have to be reduced by 18.9 percent. Reductions should improve phosphorus TSI by 2.5 percent, chlorophyll-*a* TSI by 1.2 percent and Secchi TSI by 0.8 percent, which will improve in-lake water quality. Both during and after implementing BMPs to reduce sediment, nitrogen and phosphorus loads to the lake, long-term tributary and in-lake monitoring should be conducted to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met. SD DENR will continue to monitor Brakke Dam as part of the statewide lakes assessment project.

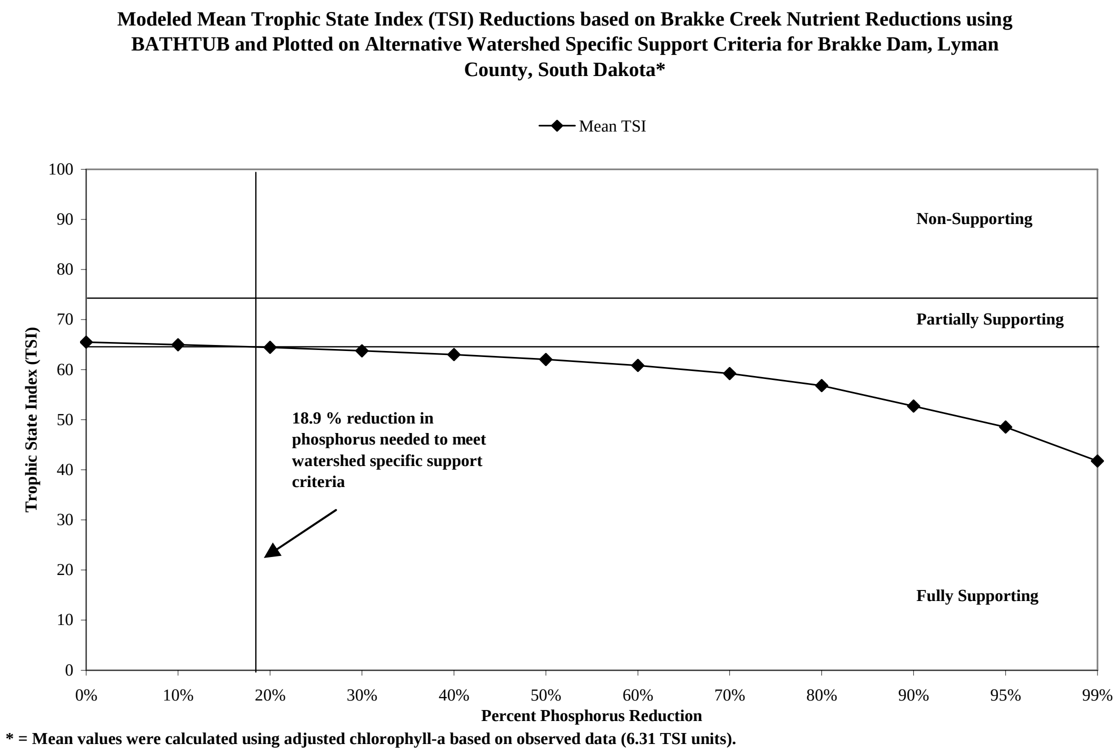


Figure 85. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 watershed-specific beneficial use categories for Brakke Dam, Lyman County, South Dakota based on 2000 and 2001 data.

The average TSI values for phosphorus, adjusted chlorophyll-*a* and Secchi combined as modeled by BATHTUB (65.49) were also in the partially supporting category (Figure 85). The recommended target for an average TSI value in Brakke Dam is 64.51 (Table 39 and Table 40). Implementing tributary BMPs in priority 1 and 2 critical cells in the watershed should decrease the in-lake mean TSI value by 1.5 percent and fully support new site-specific beneficial use criteria.

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins. An in-lake alum treatment may improve TSI values (an estimated 4.2 percent, based on modeled tributary TSI reductions); however, the Total Maximum Daily Load (TMDL) is based on attainable tributary BMP reductions using conservative targeted reduction estimates. There was little evidence of a major phosphorus load from in-lake sediments. Thus, an appropriate TMDL for total phosphorus in Brakke Dam is 501 kg/yr, producing a mean TSI of 64.51 (Table 39 and Table 40).

Over all, mean TSI values should be reduced by 1.5 percent for modeled tributary BMPs. In-lake BMPs (alum treatment (implicit margin of safety) should be implemented to achieve additional reductions (estimated approximately 4.2 percent) after tributary BMPs to achieve maximum benefit.

Table 38. Current, targeted and percent reduction for parameter specific and mean TSI values based on 2000 and 2001 data for Brakke Dam, Lyman County, South Dakota.

TSI Parameter	2000 -2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	65.33	63.72	2.5
Chlorophyll-*a*[1]	62.17	61.40	1.2
Secchi	68.97	68.41	0.8
Average	**65.49**	**64.51**	**1.5**

[1] = Chlorophyll-*a* TSI values were adjusted by measured chlorophyll-*a*

Table 39. TMDL equation for Brakke Dam, Lyman County, South Dakota based on 2000 and 2001.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ Load Allocation (LA)	501 (kg/yr)
+ Margin of Safety:	Implicit
TMDL[1]	**501 (kg/yr)**

[1] = Represents a total phosphorus tributary load reduction of approximately 18.9 percent, based upon estimated AnnAGNPS BMP attainability.

Fate Dam

Another portion of the Medicine Creek watershed assessment project also incorporated the assessment of Fate Dam and Nail Creek. The Fate Dam watershed drains an area of approximately 6,961 ha (17,202 acres) and enters Medicine Creek downstream of where Brakke Creek enters Medicine Creek. Medicine Creek tributary monitoring sites MCT-5 (upper Nail Creek) and MCT-6 (Fate Dam inlet) were located above the lake and MCT-8 (Fate Dam outlet) was located below Fate Dam on Nail Creek. Fate Dam is a recreational lake of approximately 60.7 ha (150 acres) and has been impacted by periodic algal blooms and elevated TSI values. The following is a synopsis from the complete Fate Data/Nail Creek Assessment Report and EPA approved TMDL (Smith 2004a).

Nail Creek Summary

Nail Creek was monitored using twenty separate water quality parameters. Seventeen of the twenty parameters (85 percent) had the highest average concentrations for all tributary sites in the spring of 2001. The remaining three water quality parameters (15 percent) had the highest average concentrations and/or values in the winter of 2001. During the project, Nail Creek tributary samples did not exceed water quality standards.

Nail Creek was monitored for tributary loading to Fate Dam from April 2000 through May 2001. Approximately 3,069 acre-feet of water flowed into Fate Dam from the gauged portion of the watershed (15,869 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Fate Dam/Nail Creek watershed was 0.16 acre-foot. Peak hydrologic load for the watershed occurred in the spring of 2001. Approximately 58.7 percent of the total hydrologic load delivered to Fate Dam was delivered in the spring of 2001.

Current data indicate increased nutrient loading (phosphorus) from the watershed (Nail Creek) to Fate Dam result in elevated TSI values. AnnAGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Priority areas and critical cells were listed in Fate Dam/Nail Creek Assessment Report, Appendix A (Smith, 2004a). All watershed nutrient parameters eventually affect in-lake sediment and nutrient concentrations and related TSI values in Fate Dam so reductions in any or all of these parameters may lower in-lake TSI values.

Total phosphorus loading to Fate Dam from Nail Creek is 3,440 kg/yr; at a minimum, all modeled Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Fate Dam. Based on site-specific standards for Fate Dam, a 19.5 percent reduction in total phosphorus (approximately 671 kg/yr) is needed to fully support site specific beneficial use criteria and meet the total phosphorus TMDL of 2,769 kg/yr. AnnAGNPS modeling indicated a 19.5 percent reduction in total phosphorus is attainable in the Fate Dam watershed.

Table 40. Nail Creek watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment modeling.

Parameter	Sub-watershed	Priority Ranking	Export Coefficient (kg/acre)	Delivered Load (kg)
Sediment	MCT-6	1	88.1	695,893
	MCT-5	2	68.2	541,273
Nitrogen	MCT-6	1	1.3	10,538
	MCT-5	2	1.2	9,769
Phosphorus	MCT-6	1	0.3	2,206
	MCT-5	2	0.1	835

Sub-watersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on water quality modeling export coefficients, are presented in priority ranking in Table 41.

Fate Dam In-lake Summary

Fate Dam is a 60.7 ha (150 acre) impoundment located in Lyman County, South Dakota and was included in the 1998, 2002 South Dakota's impaired waterbodies list and the 2004 Integrated Report (SD DENR, 1998; SD DENR, 2002 and SD DENR, 2004). Current data indicate Fate Dam exceeded Ecoregion 43 targeted TSI values based on mean TSI and is in need of a TMDL. However, no in-lake surface water quality samples exceeded standards during this study.

Water quality data from this study identify Fate Dam as partially supporting using assigned beneficial uses criteria based on Ecoregion 43 criteria (mean TSI ≤ 55.00). However, current ecoregional (Ecoregion 43) target criteria appear not to fit Fate Dam based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. An alternate site-specific (watershed-specific) evaluation criterion was proposed (fully supporting, mean TSI ≤ 59.00) and accepted by the US EPA for Fate Dam. Currently, even with the new criterion, Fate Dam only partially supports site specific beneficial use criteria.

Current data indicate that reductions in total phosphorus are needed in both the watershed and in Fate Dam to meet site-specific designated beneficial uses based on modeled (AnnAGNPS) attainability criteria. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Fate Dam watershed. The US EPA approved site specific evaluation criterion (fully supporting, mean TSI < 59.00) was based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability. This evaluation criterion was developed and calculated using measured loads and may not take into account long term annual load variation.

Fate Dam TMDL

Based on site-specific criteria and under current conditions, the mean TSI in Fate Dam only partially supports beneficial uses (mean TSI=59.91) using the new evaluation criterion. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Fate Dam watershed. BMP based reduction criteria for Fate Dam were estimated based on a 19.5 percent reduction in total phosphorus loads (671 kg/yr) to Fate Dam resulting in a phosphorus TMDL of 2,769 kg/yr resulting in a mean TSI of 58.91.

The 19.5 percent modeled reduction is based on AnnAGNPS watershed modeling and consisted of: (1) all priority one phosphorus fertilized fields with moderate fertilizer rates reduced one level (moderate to low) or approximately 8.8 percent phosphorus reduction; (2) converting all current pastures from fair condition to good condition or approximately 3.1 percent phosphorus reduction; (3) applying conservation tillage to all priority-one phosphorus critical cells (10-critical cells) or approximately 0.4 percent and (4) converting tilled/cropped priority-one phosphorus critical cells to all grass and results were again reduced 50 percent to better simulate typical phosphorus reduction or approximately 7.3 percent. Combining all reductions (summing all load reductions) the best estimated phosphorus reduction for the Fate Dam/Nail Creek watershed is 19.5 percent.

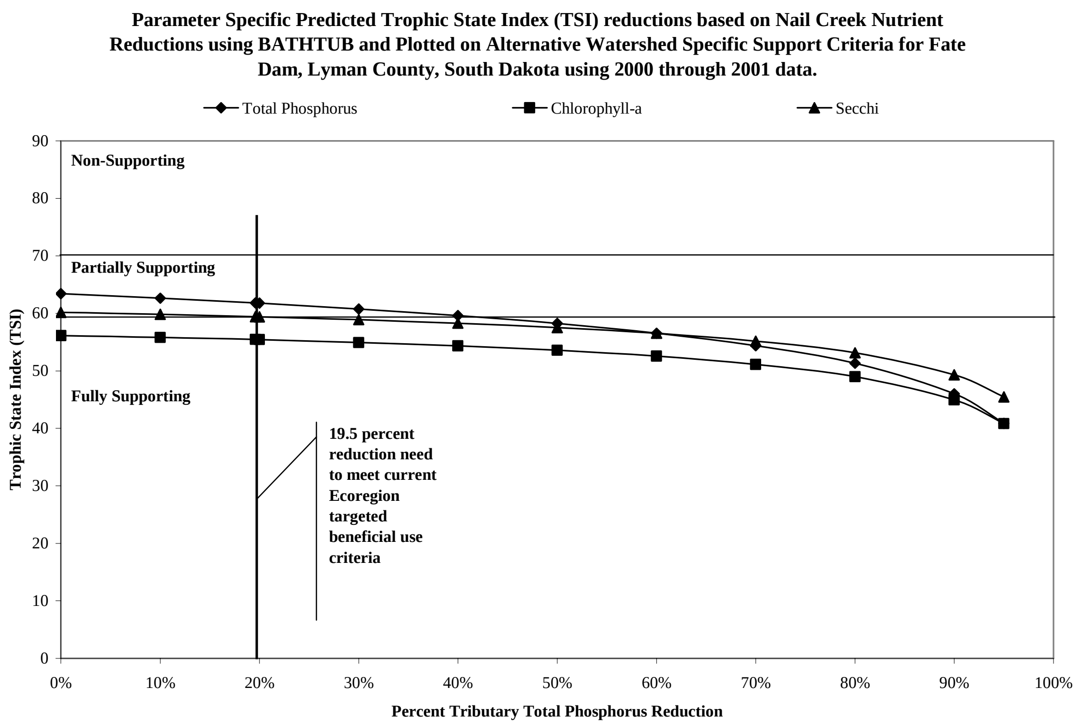


Figure 86. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Fate Dam, Lyman County, South Dakota using 2000 and 2001 data.

Targeted reductions for specific parameters and mean TSI values were modeled through the BATHTUB reduction model. All reductions were modeled or calculated using water quality and/or AnnAGNPS data collected during this study. Parameter-specific and mean TSI values were plotted on site specific beneficial use categories and are shown in Figure 86 and Figure 87, respectively. Tributary and in-lake TSI reductions were based on Best Management Practices (BMPs), best professional judgment and conversations with the American Creek Conservation District (project sponsor) to produce realistic reduction estimates. The Margin of Safety (MOS) for phosphorus is implicit. Implicit, in that, all modeled reduction estimations for tributary BMPs were calculated using extremely conservative reduction values/percentages and any additional tributary BMPs (not modeled) implemented would be incorporated in the TMDL equation as an implicit margin of safety.

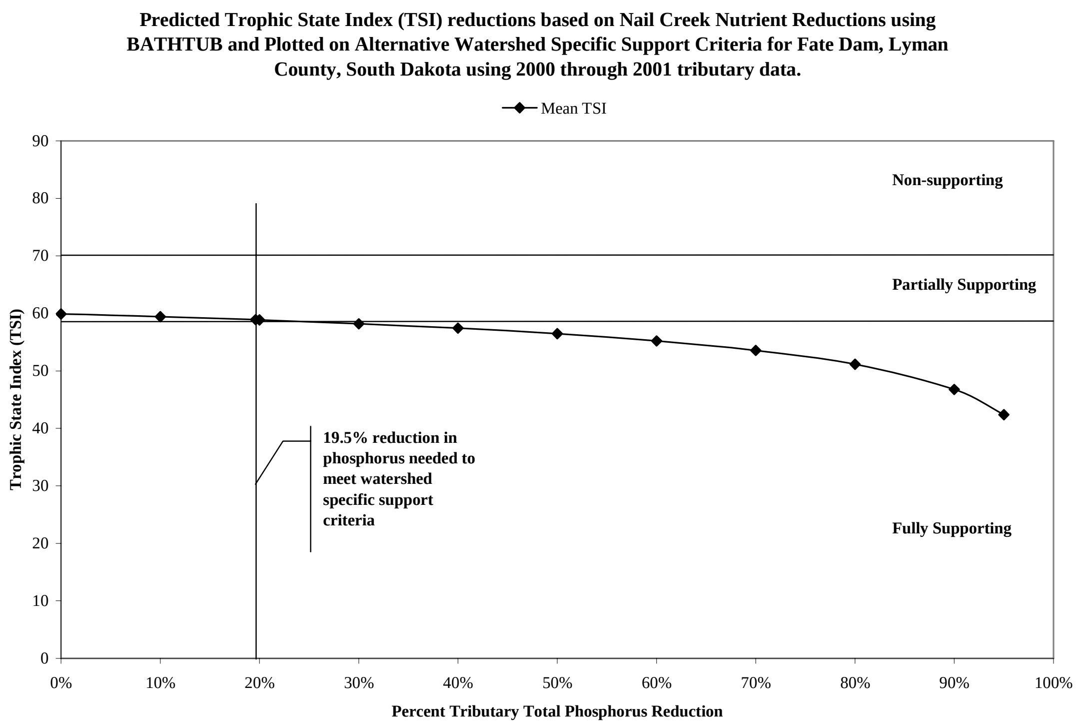


Figure 87. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 site-specific beneficial use categories for Fate Dam, Lyman County, South Dakota based on 2000 and 2001 data.

Based on 2000 and 2001 modeled data, both phosphorus TSI (63.44) and Secchi TSI (60.18) values were partially supporting; however chlorophyll-*a* TSI values (56.12) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 86). SD DENR-recommended targets for specific TSI parameters for Fate Dam were based on watershed-specific criteria and tributary BMP attainability. They are 61.82 for phosphorus, 55.48 for chlorophyll-*a* and 59.43 for Secchi visibility (Table 42). To reach these goals, tributary total phosphorus loads will have to be reduced by 19.5 percent (AnnAGNPS derived reduction). Reductions should improve phosphorus TSI by 2.6 percent, chlorophyll-*a* TSI by 1.2 percent and Secchi TSI by 1.3 percent, which will improve in-lake water quality (Table 42). Long-term tributary and in-lake monitoring should be conducted during and after implementation to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met. SD DENR will continue to monitor Fate Dam as part of the statewide lakes assessment project.

The average TSI values for phosphorus, chlorophyll-*a* and Secchi combined as modeled using BATHTUB (Table 42 (59.91)) is also in the partially supporting category (Figure 87). The recommended target for an average TSI value in Fate Dam is 58.91 (Table 42). Implementing tributary BMPs in priority 1 critical cells in the watershed should decrease the in-lake mean TSI value by 1.7 percent and fully support new site-specific beneficial use criteria (mean TSI $\leq$ 59.00).

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins to attain maximum benefit. In-lake BMPs may improve phosphorus TSI values (an estimated 8.1 percent, based on modeled (BATHTUB) in-lake TSI reductions); however, the TMDL was based on attainable tributary BMP reductions using conservative targeted reduction estimates. There was little evidence of major phosphorus load from in-lake sediments to hypolimnetic waters. An appropriate TMDL for total phosphorus in Fate Dam is 2,769 kg/yr, producing a mean TSI of 58.91 (Table 42 and Table 43).

Mean TSI values should be reduced by 1.7 percent for modeled tributary BMPs. In-lake BMPs (alum treatment (implicit margin of safety) may be implemented to achieve additional reductions (estimated approximately 8.1 percent) after tributary BMPs to achieve maximum benefit.

Table 41. Current, targeted and percent reduction for parameter specific and mean TSI values using BATHTUB based on 2000 and 2001 data for Fate Dam, Lyman County, South Dakota.

TSI Parameter	2000 -2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	63.44	61.82	2.6
Chlorophyll-*a*	56.12	55.48	1.1
Secchi	60.18	59.43	1.2
Average	**59.91**	**58.91**	**1.7**

Table 42. Total phosphorus TMDL equation for Fate Dam, Lyman County, South Dakota based on 2000 through 2001 data.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ **Load Allocation (LA)**	2,769 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**2,769 (kg/yr)**

[1] = Represents a total phosphorus tributary measured load reduction of approximately 19.5 percent, based on estimated AnnAGNPS BMP attainability.

Lake Byre

The original Medicine Creek watershed assessment project did not incorporate the assessment of the Byre Lake watershed; however, Byre Lake was incorporated into the overall project. The Byre Lake watershed drains an area of approximately 9,286 ha (22,946 acres) and enters Medicine Creek downstream of MCT-13, the last mainstem monitoring site in Kennebec, South Dakota. Medicine Creek tributary monitoring sites MCT-14 (Grouse Creek) was located above the lake and MCT-15 (Byre Lake outlet) was located below Byre Lake. Byre Lake is a 51.5 ha (127 acre) impoundment located in Lyman County, South Dakota and was not included in the 1998 and 2002 South Dakota's impaired waterbodies lists (SD DENR, 1998 and SD DENR, 2002); however, the lake was placed on the list in the 2004 Integrated Report (SD DENR, 2004).

Current data indicate Byre Lake exceeded Ecoregion 43 beneficial use standards based on mean TSI and is in need of a TMDL. The following is a synopsis from the complete Byre Lake/Grouse Creek Assessment Report and EPA approved TMDL (Smith 2003).

Grouse Creek Summary

Grouse Creek was monitored for tributary loading to Byre Lake from April 2000 through May 2001. Approximately 5,929 acre-feet of water flowed into Byre Lake from the gauged portion of the watershed (22,946 acres) in 2000 and 2001. The export coefficient (water delivered per acre) for the Byre Lake/Grouse Creek watershed was 0.27 acre-foot. Peak hydrologic load for the watershed occurred in the spring. Approximately 96 percent of the total hydrologic load delivered to Byre Lake was delivered in the spring of 2001.

Grouse Creek was monitored using nineteen water quality parameters, with a large percentage (68.4 percent) having the highest average concentrations and values for both tributaries (Grouse Creek inlet (MCT-14) and outlet (MCT-15)) in the spring of 2001. The remaining six water quality parameters (31.6 percent) had the highest average concentrations and values in the winter of 2001.

No fecal coliform standards violations were observed in the Grouse Creek watershed during this study (bacteria standards in effect from May 1 through September 30). Although no violations occurred, elevated fecal coliform counts were collected from both tributary sampling sites in April 2001. Most high fecal coliform counts (> 1,000 colonies/100 ml) were collected during peak flow conditions in late April of 2001. Runoff from land-applied manure may be responsible for the sporadic high fecal concentrations. Since the majority of the Byre Lake/Grouse Creek watershed is agricultural, most elevated fecal coliform counts can be attributed to agricultural runoff.

Table 43. Grouse Creek watershed mitigation priority sub-watersheds for sediment, nitrogen and phosphorus, based on watershed assessment modeling.

Parameter	Sub-watershed	Priority Ranking	Export Coefficient (kg/acre)	Delivered Load (kg)
Sediment	MCT-14	1	231.99	4,797,761
	MCT-15	2	18.29	419,716
Nitrogen	MCT-14	1	0.87	17,922
	MCT-15	2	0.57	13,152
Phosphorus	MCT-14	1	0.45	9,391
	MCT-15	2	0.11	2,493

Total phosphorus loading to Byre Lake was 9,391 kg/yr; all recommended Best Management Practices (BMPs) should be implemented in the watershed to reduce the nutrient (phosphorus) loading to Byre Lake. Based on site-specific standards for Byre Lake, a 19.6 percent reduction in total phosphorus (1,841 kg/yr) is needed to fully support adjusted beneficial use criteria and meet the total phosphorus TMDL of 7,550 kg/yr. AnnAGNPS modeling indicates a 19.6 percent reduction in total phosphorus is attainable in the Byre Lake watershed.

Sub-watersheds that should be targeted for sediment, nitrogen and total phosphorus mitigation, based on water quality modeling export coefficients, are presented in priority ranking in Table 44.

Byre Lake In-lake Summary

The surface samples at two in-lake monitoring sites in Byre Lake exceeded in-lake water quality standards for pH on May 15, 2001. Surface pH in Byre Lake in May of 2001 was the highest pH values recorded during the project. These violations were in conjunction with the largest algal bloom during the project. Algal blooms are known to increase pH in lakes; by reducing in-lake phosphorus concentrations the frequency of nuisance algal blooms may be reduced, mitigating in-lake pH concerns.

Current data indicate that a reduction in total phosphorus is needed in both the watershed and in Byre Lake to meet site-specific designated beneficial uses based on modeled attainability criteria. Decreasing tributary sediment, nitrogen and phosphorus inputs from Grouse Creek will improve (lower) Byre Lake TSI values. Tributary reductions in these parameters will reduce Secchi, total phosphorus and chlorophyll-*a* TSI values and increase transparency. Increasing transparency should increase the growth of submerged macrophytes, which would increase the uptake of nitrogen and phosphorus, reducing available nutrients that cause algal blooms. Increasing densities of submerged macrophytes will also create littoral zone cover for macroinvertebrates, forage fish, and ambush points for predator species. Every effort should be made to improve current management practices to control and reduce sediment and nutrient runoff in the Byre Lake watershed.

Mean TSI values were originally used to set current ecoregional beneficial use criteria for lakes in South Dakota (SD DENR, 2000a). However, current ecoregional (Ecoregion 43) target criteria appear not to fit Byre Lake based on AnnAGNPS watershed loading and BATHTUB in-lake eutrophication modeling. An alternative site specific (watershed-specific) evaluation criteria (fully supporting, mean TSI $\leq$ 65.00) was proposed and approved by US EPA based on AnnAGNPS modeling, BMPs and watershed-specific phosphorus reduction attainability.

Based on site-specific criteria and under current conditions (mean TSI 66.24), Byre Lake only partially supports beneficial uses using this evaluation criteria. The site (watershed) specific criteria/goals are more realistic and attainable based on AnnAGNPS modeling and BMP reductions within the Byre Lake watershed. BMP based reduction criteria for Byre Lake were estimated based on a 19.6 percent reduction in total phosphorus loads (1,841 kg/yr) resulting in a phosphorus TMDL of 7,550 kg/yr producing a mean TSI of 65.00.

Byre Lake TMDL

Targeted reductions for specific parameters and mean TSI values were modeled through the BATHTUB reduction model. All reductions were modeled or calculated using water quality and/or AGNPS data collected during this study. Parameter-specific and mean TSI values were plotted on the new site specific beneficial use categories and are shown in Figure 88 and Figure 89. Tributary and in-lake TSI reductions were based on BMPs and best professional judgment. The margin of safety for phosphorus is implicit. Meaning all reduction estimations for tributary and in-lake reductions were calculated using extremely conservative reduction values/percentages.

Based upon 2000 and 2001 loading data, both phosphorus TSI (69.76) and Secchi TSI values were partially supporting; however chlorophyll-*a* TSI values (60.61) were fully supporting based on previously defined watershed-specific beneficial use criteria (Figure 88). SD DENR-recommended targets for specific TSI parameters for Byre Lake were based on watershed-specific criteria and tributary BMP attainability. They are 68.02 for phosphorus, 59.96 for chlorophyll-*a* and 67.02 for Secchi transparency (Table 45). To reach these goals, tributary total phosphorus loads will have to be reduced by 1,841 kg/yr (19.6 percent). Reductions should improve phosphorus TSI by 2.5 percent, chlorophyll-*a* TSI by 1.1 percent and Secchi TSI by 2.9 percent, which will improve in-lake water quality and help meet the TMDL based on site specific criteria. Both during and after implementing BMPs to reduce sediment, nitrogen and phosphorus loads to the lake, long-term tributary and in-lake monitoring should be conducted to evaluate BMPs' effectiveness and determine if in-lake TSI targets have been met.

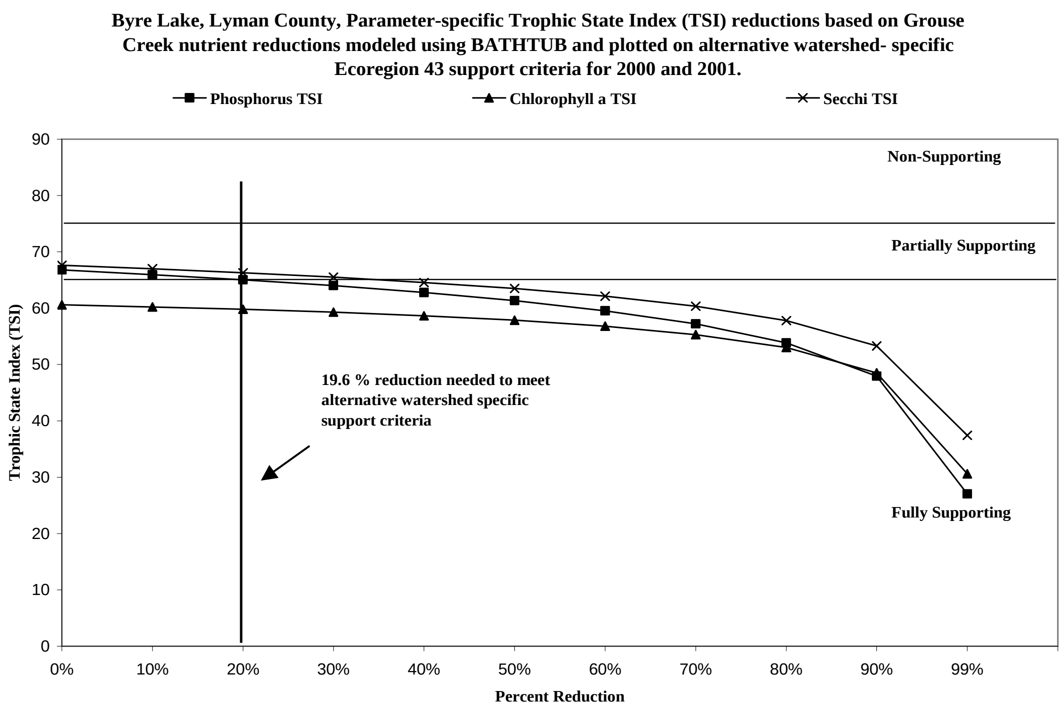


Figure 88. TMDL-predicted parameter specific Trophic State Index (TSI) reductions using the BATHTUB reduction model based on tributary BMPs reductions and ranked by watershed-specific beneficial use categories for Byre Lake, Lyman County, South Dakota using 2000 and 2001 data.

The average TSI values for phosphorus, chlorophyll-*a* and Secchi combined (66.24), as modeled by BATHTUB, were also in the partially supporting category (Figure 89). The recommended target for an average TSI value in Byre Lake is 65.00 (Table 45). Implementing tributary BMPs in AnnAGNPS derived priority 1 and 2 critical cells in the watersheds will decrease the in-lake mean TSI value by 1.9 percent and fully support site-specific beneficial use criteria.

If an in-lake alum treatment is considered, all tributary BMPs should be in place and implemented before alum treatment begins. In-lake BMPs will improve TSI values (an estimated 4.9 percent, based on modeled tributary TSI reductions); however, the Total Maximum Daily Load (TMDL) is based on attainable tributary BMP reductions using conservative targeted reduction estimates.

An appropriate TMDL for total phosphorus in Byre Lake is 7,550 kg/yr, producing a mean TSI of 65.00 (Table 46). The nonpoint source/background load allocation for phosphorus is 7,550 kg/yr based on 2000 through 2001 total phosphorus and hydrologic loads to Byre Lake (Table 45 and Table 46).

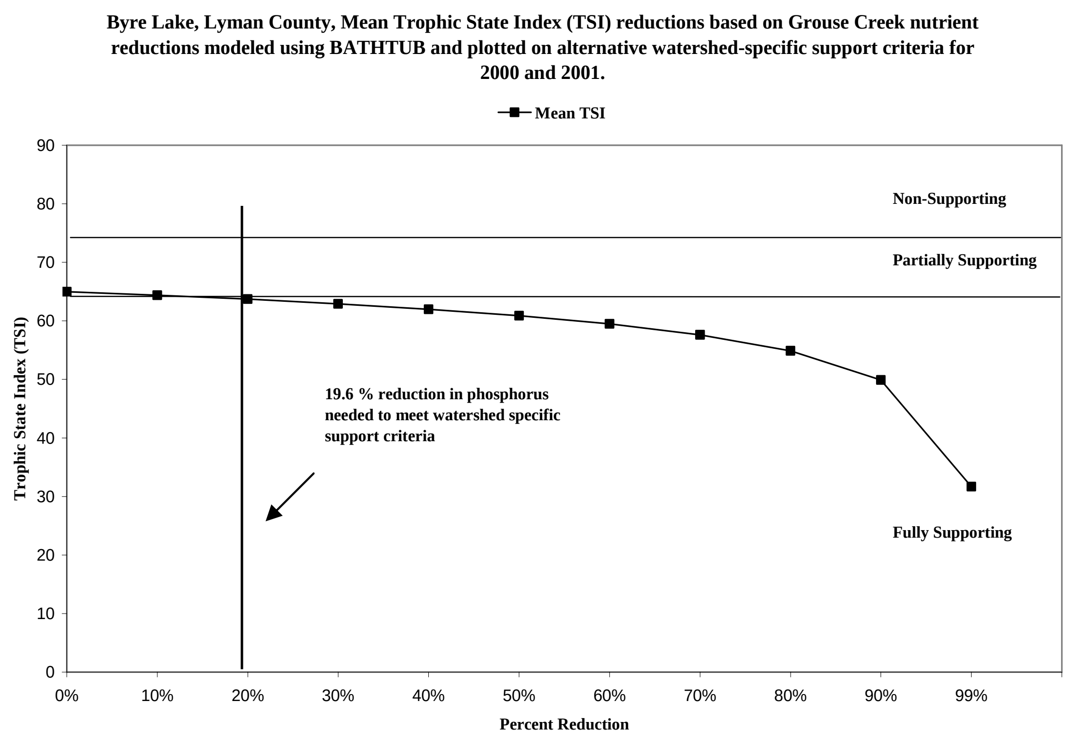


Figure 89. TMDL-predicted mean Trophic State Index (TSI) reduction using the BATHTUB reduction model based on tributary BMPs reductions ranked by Ecoregion 43 watershed-specific beneficial use categories for Byre Lake, Lyman County, South Dakota based on 2000 and 2001 data.

Table 44. Current, targeted and percent reduction based on BATHTUB for parameter-specific and mean TSI values based on 2000 and 2001 water quality data for Byre Lake, Lyman County, South Dakota.

TSI Parameter	2001 Estimated TSI Values (BATHTUB)	TMDL Targeted TSI Value	Percent TSI Reduction
Total Phosphorus	69.76	68.02	2.5
Chlorophyll-*a*	60.61	59.96	1.1
Secchi	68.34	67.02	1.9
Average	**66.24**	**65.00**	**1.9**

Table 45. TMDL equation for Byre Lake, Lyman County, South Dakota, based on 2000 and 2001 data.

Component	Maximum Load
Waste Load Allocation (WLA):	0 (kg/yr)
+ **Load Allocation (LA)**	7,550 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**7,550 (kg/yr)**

[1] = Represents a total phosphorus tributary load reduction of 19.6 percent, based upon BMP attainability.

Fisheries Data

South Dakota Game, Fish and Parks (SD GF&P) have not conducted extensive fishery surveys in Medicine Creek; however, fish surveys have been conducted on Byre Lake, Brakke Dam and Fate Dam by SD GF&P. The only data SD GF&P has on Medicine Creek are two stocking reports indicating 1,600 brook trout fingerlings and 8,000 rainbow trout fingerlings were stocked in the creek in 1930. Fishery summaries and complete SD GF&P reports on each lake in the watershed can be reviewed by assessment report for Byre Lake in Smith 2003, Brakke Dam in Smith 2004 and Fate Dam in Smith 2004a, respectively. Copies of these reports can be obtained by contacting SD DENR at (605) 773-4254 or at: http://www.state.sd.us/denr/denr.html

Endangered Species

The South Dakota Natural Heritage Database identified one species, the whooping crane, as being endangered in the Medicine Creek watershed. This database contains documented identifications of rare, threatened or endangered species across the state and is listed in Appendix F. The whooping crane (*Grus americana*), a federally-listed endangered species, has been recorded in the Medicine Creek watershed. Two observations were recorded in the watershed, the first observation (October 29, 1997) indicated 3 cranes flying over and another on May 7, 1998 where a crane was on the ground for five days. The State of South Dakota lists the whooping crane as SZN, nonbreeding, no definable occurrences for conservation purposes, a category usually assigned to migrants. There are no other federal or state threatened or endangered species documented in the Medicine Creek watershed; however, six species are identified as being rare. Species identified as rare in the Medicine Creek watershed were five bird species, Swainson's hawk (*Buteo swainsoni*), Ferruginous hawk (*Buteo regalis*), Burrowing owl (*Athene cunicularia*), Baird's sparrow (*Ammodramus* bairdii) and Sprague's pipit (*Anthus spragueii*). The Baird's sparrow (*Ammodramus* bairdii) and Sprague's pipit (*Anthus spragueii*) are state listed as S2B as imperiled because of rarity or because of some other factor(s) making it very vulnerable to extinction throughout its range. One mammal species was also listed as rare, Plains spotted skunk (*Spilogale putorius interrupt).* The US Fish and Wildlife Service lists the bald eagle, and western prairie fringed orchid as species that could potentially be found in the area. None of these species were encountered during this study; however, care should be taken when conducting mitigation projects in the Medicine Creek watershed.

3.5 Quality Assurance Reporting

Twenty five quality assurance and quality control (QA/QC) samples were collected throughout the 2000 and 2001 sampling periods for tributary monitoring sites in Medicine Creek (14 blank and 11 replicate). Standard chemical analysis was performed on all blank and replicate samples collected. Analyses followed tributary standard routine chemical parameters for analysis and are listed in Table 2.

Replicate samples were compared to the original samples using the industrial statistic (%I). The value given is the absolute difference between the original and the replicate sample expressed as a percent and is provided shown in Equation 10.

Equation 9. Industrial statistic equation.

$$\%I = (A-B) / (A+B)*100$$

Where: %I = Industrial Statistic
(A-B) = Absolute difference
(A+B) = Absolute sum

Blank samples were evaluated by calculating the mean and standard deviation of all blank samples for all tributary sites collected during the study. The criterion for compliance was that the standard deviation be less than the mean of all blank samples collected (Table 47). All blank quality assurance/quality control tributary samples were in compliance with criterion proposed above with the standard deviation being less than the mean for each chemical parameter. Some variations, especially in total solids and total dissolved solids parameters, were attributed to different brands of distilled water produced using a variety of manufacturing techniques and QA/QC standards resulting in differences in elevated total and total dissolved solids concentrations in blank samples.

Eleven tributary replicate samples were collected in Medicine Creek during the project for an overall quality assurance/quality control percentage of 9.3 percent. Ten tributary replicate sample parameters (fecal coliform, E. coli, total solids, total suspended solids, volatile total suspended solids, total phosphorus, total dissolved phosphorus, ammonia and organic nitrogen (related parameters)) had an industrial statistic (%I) greater than 10 percent (absolute percent). Fecal coliform and *E. coli* colony counts often vary due to variations in sunlight, bacterial growth on incubated media and temperature. Total solids, total dissolved solids, total suspended solids and volatile total suspended solids concentrations can vary considerably because of variations in sample collection and processing. Only one violation in both total solids and total dissolved solids and two replicate samples of total suspended solids violated the adopted criterion. Approximately 45.5 percent of volatile total suspended solids had industrial statistics greater than 10 percent. Five ammonia and two organic nitrogen (related parameters) QA/QC sample sets exceeded protocol limits during the study. One total phosphorus and two total dissolved phosphorus sample sets exceeded criteria. Over all, 84.1 percent of all tributary industrial statistics values were less than 10 percent different (Table 48). Variations in field sampling techniques, preparation and that the samples are replicate and not duplicate may be some reasons for differences.

In-lake QA/QC sample results for Byre Lake, Brakke Dam and Fate Dam may be reviewed in their respective assessment reports (Smith 2003, Smith 2004 and Smith 2004a).

Table 46. Tributary blank quality assurance/quality control samples collected in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Sample Type	Site	Date	Depth	Water Temp (° C)	Fecal Coliform (#/100 ml)	E. coli (#/100 ml)	Alkalinity (mg/L)	Total Solid (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
blank	MCT	04/12/00	-	-	5		6	7	7	1	1	0.21	0.01	0.10	0.20	0.11	0.31	0.002	0.002
blank	MCT	02/06/01	-	-	5		11	44	44	1	1	0.36	0.01	0.40	0.35	0.41	0.76	0.002	0.002
blank	MCT	03/05/01	-	-	5		6	8	8	1	1	0.36	0.01	0.20	0.35	0.21	0.56	0.002	0.002
blank	MCT	05/13/01	-	-	5	1	6	10	10	1	1	0.36	0.01	0.20	0.35	0.21	0.56	0.002	0.002
blank	MCT	05/13/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.003
blank	MCT	05/13/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/15/01	-	-	5	1	6	8	8	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/15/01	-	-	5	1	6	9	9	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/16/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/22/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.037
blank	MCT	05/23/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/23/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
blank	MCT	05/23/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.70	0.35	0.71	1.06	0.002	0.002
blank	MCT	05/23/01	-	-	5	1	6	7	7	1	1	0.36	0.01	0.10	0.35	0.11	0.46	0.002	0.002
				Mean	5	1	8	16	16	1	1	0.35	0.01	0.18	0.34	0.19	0.53	0.002	0.004
				Standard Deviation	0.00	0.00	1.34	9.79	9.79	0.00	0.00	0.04	0.00	0.17	0.04	0.17	0.18	0.000	0.009

Table 47. Tributary routine and replicate quality assurance/quality control samples collected in Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Sample Type	Site	Date	Depth	Water Temp (° C)	Fecal Coliform (#/100 ml)	E. coli (#/100 ml)	Alkalinity (mg/L)	Total Solid (mg/L)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Volatile Total Suspended Solids (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Organic Nitrogen (mg/L)	Inorganic Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)
Routine	MCT-1A	05/22/01	Surface	12.85	400	260.00	278	2,876	2,870	6.0	1	2.25	0.01	30.90	2.24	30.91	33.15	0.054	0.025
Replicate	MCT-1A	05/22/01	Surface	12.85	210	225.00	280	2,861	2,854	7.0	1	2.32	0.01	31.00	2.31	31.01	33.32	0.052	0.026
	Industrial Statistic (I%)			0.00%	**31.15%**	7.22%	0.36%	0.26%	0.28%	7.69%	0.00%	1.53%	0.00%	0.16%	1.54%	0.16%	0.26%	1.89%	1.96%
Routine	MCT-2	05/22/01	Surface	13.52	150	148.00	280	2,952	2,936	16.0	2	1.39	0.01	3.30	1.38	3.31	4.69	0.083	0.020
Replicate	MCT-2	05/22/01	Surface	13.52	200	120.00	277	5,950	5,931	19.0	3	1.53	0.03	3.30	1.50	3.33	4.83	0.082	0.031
	Industrial Statistic (I%)			0.00%	14.29%	**10.45%**	0.54%	**33.68%**	**33.78%**	8.57%	**20.00%**	4.79%	**50.00%**	0.00%	4.17%	0.30%	1.47%	0.61%	**21.57%**
Routine	MCT-4	04/05/01	Surface	7.09	10	2.00	110	434	429	5.0	2	0.61	0.01	0.10	0.60	0.11	0.71	0.220	0.179
Replicate	MCT-4	04/05/01	Surface	7.09	10	4.10	110	429	425	4.0	2	0.57	0.02	0.10	0.55	0.12	0.67	0.216	0.184
	Industrial Statistic (I%)			0.00%	0.00%	**34.43%**	0.00%	0.58%	0.47%	**11.11%**	0.00%	3.39%	**33.33%**	0.00%	4.35%	4.35%	2.90%	0.92%	1.38%
Routine	MCT-6	04/26/01	Surface	14.19	200	365.00	113	576	380	196.0	24	1.76	0.06	3.40	1.70	3.46	5.16	0.621	0.306
Replicate	MCT-6	04/26/01	Surface	14.19	170	222.00	112	563	383	180.0	20	1.17	0.04	3.50	1.13	3.54	4.67	0.624	0.327
	Industrial Statistic (I%)			0.00%	8.11%	**24.36%**	0.44%	1.14%	0.39%	4.26%	9.09%	**20.14%**	**20.00%**	1.45%	**20.14%**	1.14%	4.98%	0.24%	3.32%
Routine	MCT-7	05/22/01	Surface	13.94	5	9.50	214	658	581	77.0	8	0.87	0.03	0.10	0.84	0.13	0.97	0.266	0.064
Replicate	MCT-7	05/22/01	Surface	13.94	5	8.50	213	657	574	83.0	10	0.86	0.03	0.10	0.83	0.13	0.96	0.115	0.048
	Industrial Statistic (I%)			0.00%	0.00%	5.56%	0.23%	0.08%	0.61%	3.75%	11.11%	0.58%	0.00%	0.00%	0.60%	0.00%	0.52%	**39.63%**	**14.29%**
Routine	MCT-9	05/13/01	Surface	22.03	130	108.00	189	2,062	1,990	72.0	4	2.27	0.01	5.80	2.26	5.81	8.07	0.164	0.045
Replicate	MCT-9	05/13/01	Surface	22.03	120	95.80	192	2,073	1,997	76.0	8	2.45	0.01	5.80	2.44	5.81	8.25	0.152	0.041
	Industrial Statistic (I%)			0.00%	4.00%	5.99%	0.79%	0.27%	0.18%	2.70%	**33.33%**	3.81%	0.00%	0.00%	3.83%	0.00%	1.10%	3.80%	4.65%
Routine	MCT-9	05/23/01	Surface	11.04	130	111.00	240	2,442	2,422	20.0	2	1.60	0.01	4.20	1.59	4.21	5.80	0.055	0.026
Replicate	MCT-9	05/23/01	Surface	11.04	70	79.80	236	2,436	2,417	19.0	1	1.78	0.01	4.20	1.77	4.21	5.98	0.067	0.020
	Industrial Statistic (I%)			0.00%	**30.00%**	**16.35%**	0.84%	0.12%	0.10%	2.56%	**33.33%**	5.33%	0.00%	0.00%	5.36%	0.00%	1.53%	9.84%	**13.04%**
Routine	MCT-10	05/23/00	Surface	11.9	80	-	123	244	213	31.0	4.0	0.81	0.01	0.30	0.80	0.31	1.11	0.112	0.061
Replicate	MCT-10	05/23/00	Surface	11.9	10	-	123	245	220	25.0	3.0	0.81	0.01	0.30	0.80	0.31	1.11	0.114	0.060
	Industrial Statistic (I%)			0.00%	**77.78%**	-	0.00%	0.20%	**1.62%**	**10.71%**	**14.29%**	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.88%	0.83%
Routine	MCT-13	06/01/00	Surface	19.30	160	-	199	3,652	3,607	45.0	6	2.33	0.01	6.00	2.32	6.01	8.33	0.117	0.022
Replicate	MCT-13	06/01/00	Surface	19.30	120	-	199	3,654	3,612	42.0	6	2.18	0.01	6.00	2.17	6.01	8.18	0.124	0.024
	Industrial Statistic (I%)			0.00%	14.29%	-	0.00%	0.03%	0.07%	3.45%	0.00%	3.33%	0.00%	0.00%	3.34%	0.00%	0.91%	2.90%	4.35%
Routine	MCT-13	05/23/01	Surface	12.11	250	185.00	201	2,100	2,074	26.0	2	1.11	0.02	7.90	1.09	7.92	9.01	0.060	0.016
Replicate	MCT-13	05/23/01	Surface	12.11	230	172.00	201	2,105	2,079	26.0	2	1.83	0.01	7.90	1.82	7.91	9.73	0.065	0.019
	Industrial Statistic (I%)			0.00%	4.17%	3.64%	0.00%	0.12%	0.12%	0.00%	0.00%	**24.49%**	**33.33%**	0.00%	**25.09%**	0.06%	3.84%	4.00%	8.57%
Routine	MCT-14	05/22/01	Surface	16.86	5	-	113	372	331	41.0	4.0	1.08	0.02	1.00	2.08	1.06	1.02	0.236	0.155
Replicate	MCT-14	05/22/01	Surface	16.86	5	-	105	373	334	39.0	7.0	0.95	0.01	1.00	1.95	0.94	1.01	0.249	0.157
	Industrial Statistic (I%)			0.00%	0.00%	-	3.67%	0.13%	0.45%	2.50%	**27.27%**	6.40%	**33.33%**	0.00%	3.23%	6.00%	0.49%	2.68%	0.64%

3.6 Monitoring Summary and Recommendations

Monitoring Summary

Tributary

Medicine Creek is listed in the 2004 Integrated Report for total dissolved solids and conductivity (SD DENR 2004). Medicine Creek drains a watershed of approximately 157,857 ha (390,072 acres) from approximately Draper, South Dakota to the boundary of Lower Brule Tribal Reservation, Lyman County, South Dakota (Figure 1). Three reservoirs Fate Dam, Brakke Dam and Byre Lake and their respective watersheds are within the Medicine Creek watershed. These reservoirs are also listed in the 2004 Integrated Report for TSI (Trophic State Index) exceeding the ecoregion 43 (Northwestern Great Plains) target standard of mean TSI $\leq$ 55.00 (SD DENR 2004) and require TMDLs.

All reservoirs within the watershed were assessed separately in conjunction with the Medicine Creek watershed assessment project. Three assessment reports and TMDLs have been completed and accepted by US EPA, Region VIII (see Byre Lake/Grouse Creek Assessment and TMDL in Smith 2003, Brakke Dam/Brakke Creek Assessment and TMDL in Smith 2004 and Fate Dam/Nail Creek Assessment and TMDL in Smith 2004a). All projects in this were sponsored and supported the American Creek Conservation District (ACCD) in Kennebec, South Dakota.

Assigned beneficial uses for Medicine Creek are as follows: (6) Warmwater marginal fish life propagation waters, (8) Limited-contact recreation waters, (9) Fish and wildlife propagation, recreation, and stock watering water and (10) Irrigation water, all with specific water quality standards. Only assessment data collected from mainstem Medicine Creek sites (Highway 83 to Kennebec, MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) were used to determine water quality standards violations in the Medicine Creek stream segment (S149, Integrated Report, page 131 (SD DENR, 2004)). The WQM site on Medicine Creek at Kennebec, South Dakota (DENR 460141, WQM 141) was also the location of the downstream sampling site during the assessment (MCT-13).

Twenty-four water quality standard violations in five parameters were observed during the assessment; while, 46 water quality standards violations in six parameters were observed in Water Quality Monitoring (WQM) data based on assigned beneficial uses for Medicine Creek (Table 8 through Table 13). Water quality standard violations categories during the assessment were specific conductance (conductivity @ 25° C), TDS, TSS, dissolved oxygen and fecal coliform. WQM sample violation categories were similar to assessment violations but also included pH. Currently, 303(d) and Integrated Report listing criteria for waters needing a TMDL are $\geq$ 10 percent violations with a minimum of 20 total samples.

Medicine Creek is listed in The 2004 South Dakota Integrated Report for Surface Water Quality Assessment (305(b) report and 303(d) list combined) as impaired for conductivity and TDS (2004 Integrated Report (page 131)) based on assigned beneficial use standards criteria for a 9, 10 stream, fish and wildlife propagation, recreation and stock watering water and irrigation water, respectively. Monthly, event based and groundwater seep samples collected during the assessment and WQM data support this listing; however, TSS and fecal coliform bacteria samples also violated assigned beneficial use based standards for warmwater marginal fish life propagation water and limited contact recreation water (assigned beneficial uses 6 and 8, respectively).

The overall violation percentage for specific conductance was 20.7 percent (22 violations out of 106 total samples) while the violation percentage for TDS was 18.5 percent (23 violations out of 124 total samples) and confirmed the Integrated Report listing for these parameters. Data from this report indicate that water quality standard violations in specific conductance were caused by high TDS concentrations in mainstem Medicine Creek, especially during low flows, and were naturally occurring due to unique geological conditions in the Pierre Shale formation.

Specific conductance values (conductivity) and TDS concentrations were significantly related in Medicine Creek both overall (Figure 12) and by site comparisons (Figure 13) with a correlation coefficient of r = 0.96. The linear relationship of specific conductance to flow (R^2) was high at 0.87 and the relationship of TDS to flow was also significant at 0.83. Indicating 87 percent of the variation in specific conductance values and 83 percent of the variation in TDS concentrations were explained by discharge/flow. With the strong relationship of specific conductance and TDS to flow, spatial analysis was used to determine areas of high specific conductance values and TDS concentrations. All specific conductance values and TDS concentrations in monitored tributaries to Medicine Creek (MCT-3, MCT-4, MCT-5, MCT-6, MCT-7, MCT-8, MCT-10, MCT-11, MCT-12, MCT-14 and MCT-15) were significantly lower (p=0.000) than mainstem sites (MCT-1, MCT-1A, MCT-2, MCT-9 and MCT-13) suggesting mainstem Medicine Creek has down cut more into the Pierre Shale formation. This situation may have exposed more of mainstem Medicine Creek to groundwater flow creating seeps and upwelling of interstitial waters at the groundwater streamwater mixing zone (hyporheic zone) resulting in extended flow duration during drought conditions. The combination of seeps and groundwater dominated recharge in mainstem Medicine Creek appear to increase TDS and specific conductance during low flows.

Two seep samples were collected in Medicine Creek and compared to seep and well samples from the Freeman watershed (a nearby watershed located in the Pierre Shale formation). Medicine Creek seep samples show similar high concentrations of TDS, nitrates, sulfate, sodium, selenium and specific conductance values as did Freeman Dam (Table 20). Three constituents of TDS, Sodium (Na^+), Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) were used to calculate SAR ratios in two seep samples collected in the Medicine Creek watershed. These were calculated to estimate the potential impact the seeps (contributing high TDS concentrations and specific conductance values) may have on their respective tributaries. The SAR standard ($\leq$ 10 milliequivalents per liter (me/L)) applies to most streams of the State with beneficial use based water quality standard for 10-irrigation waters (exception Belle Fourche River where SAR concentrations must be below 6 milliequivalents per liter). SAR results for seep samples exceeded the water quality standard (Anderson 1, 36.0 me/L and Urban 1, 107.6 me/L) and suggest that seeps originating in the Pierre Shale formation have high SAR. Seep SAR sample data support the conclusion that high TDS concentrations in Medicine Creek originate from groundwater and ground water seeps that naturally occur in various locations in the Pierre Shale formation.

Data from Freeman Dam and Medicine Creek indicate that under certain conditions, high TDS, nitrate, sulfate, sodium, selenium concentrations and specific conductance values occur and may be common throughout the Pierre Shale formation. High specific conductance values and TDS concentrations recorded in Medicine Creek during low flows/discharge were attributed to groundwater dominated flow and Pierre Shale seeps with high concentrations of TDS, nitrate, sodium, sulfate and selenium (Table 20). Violations in assigned beneficial use water quality standards in Medicine Creek for specific conductance and TDS concentrations during low flow conditions should be considered a natural condition in this watershed.

Based on naturally occurring TDS concentrations in seep and groundwater, Medicine Creek can not meet current water quality standards for TDS or specific conductance (conductivity) especially at low flow conditions. Current and long-term data suggest that in mainstem Medicine Creek, high TDS concentrations result in high specific conductance (conductivity @ 25° C) values and occur throughout the watershed, especially during low flows due to natural (geological) conditions.

The overall TSS violation rate was 10.0 percent (12 violations out of 120 total samples) which is below the listing criteria; however, the violation rate during the assessment was 11.3 percent (7 violations out of 62 total samples). Because the overall violation percentage rate for assessment data was over the listing criteria (> 10 percent), a TMDL was developed for TSS in Medicine Creek.

Attainable TSS load reduction percentages estimated by AnnAGNPS were modeled using the FLUX program to calculate the appropriate TSS LA for Medicine Creek. To calculate the reduction in TSS load, the overall TSS violation percentage (10.0 percent) was used to reduce 10 percent of the assessment concentrations at MCT-13 (1 sample out of 10 total samples collected) and re-run the FLUX model using the adjusted concentration data (adjusting one TSS sample violation to the water quality standard (1,220 mg/L to 263 mg/L) with the original 2000 through 2001 hydrologic load. Because most violations occurred during high flow events, the realized modeled reduction percentage (20.1 percent) was greater than the initial modeled reduction (10 percent).

The TSS TMDL for Medicine Creek is to reduce the current annual load allocation to 20,164,594 kg/yr or approximately 20.1 percent producing a TSS TMDL of 20,172,490 kg/year (an approximate overall reduction of 20 percent) with an implicit MOS (Table 51). All TSS load reductions needed to meet the TMDL come exclusively from the load allocation (LA) because no realistic reduction can be expected from the waste load allocation (WLA).

Similar to TSS, Medicine Creek was not listed in the 2004 South Dakota Integrated Report as being impaired for fecal coliform; however, data show that 12.1 percent of all fecal coliform samples collected from May through September in Medicine Creek violated assigned surface water quality standards for fecal coliform (Table 12). TMDL listing criteria for South Dakota waters are if 10 percent or more of samples (20 sample minimum) exceed the water quality standard the site is impaired and requires a TMDL (SD DENR, 2004).

South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30, elevated fecal coliform bacteria are an indicator of potential human health concerns. Seven water quality violations in fecal coliform standards have been documented since 2000, five assessment samples and two WQM samples (Table 12). Two violations occurred in June and three in July of 2000 during the assessment. All fecal coliform violations collected during the assessment were collected at low flow conditions. Figure 78 indicates four of the five violations occurred during the summer sampling period which had the lowest flows. However, nine fecal coliform samples collected in April of 2001 (outside the standards window) were well above 2,000 colonies/100 ml and were collected during high flows events. In April, fecal coliform counts ranged from 150,000 colonies/100 ml to 5 (½ the detection limit). During April seven of the nine fecal coliform sample violations exceeded 2,000 colonies/100 ml were collected on mainstem Medicine Creek monitoring sites. Based on current data, fecal coliform is considered a problem requiring development of a fecal coliform TMDL for Medicine Creek.

TMDL development for fecal coliform bacteria consisted of calculating yearly WLAs (Waste Load Allocations) in conjunction with SD DENR SWQP (Surface Water Quality Program) for all point sources that potentially discharge to mainstem Medicine Creek, model/estimate attainable fecal coliform load reductions from the watershed using assessment data and the MOS Margin-Of-Safety was considered implicit in that all LA (Load Allocations) were calculated using conservative reduction estimates. To calculate the appropriate fecal coliform load reduction, the assessment fecal coliform violation percentage (approximately 16.0 percent) was used to calculate the reduction needed in average delivered waste load per animal (estimate the number of animals to reduce to meet the required load reduction based on the delivered fecal coliform load per animal (4.72×10^9 cfu/100 ml/animal) to meet the fecal coliform TMDL.

The WLA (Waste Load Allocation) was calculated using the fecal coliform standard for limited contact waters (2,000 cfu/100 ml) and potential discharge from each facility provided by SD DENR SWQP. WLA was calculated using conservative discharge calculations and accounted for increased rainfall events and future municipal growth. The wastewater ponds at Presho are approximately 23.8 stream kilometers (14.8 stream miles) upstream from Kennebec, fecal coliform originating from the Presho facility and traveling downstream to Kennebec would be exposed to mixing and increased exposure to ultraviolet light resulting in fecal decay. To account for this, the exponential decay rate was used to calculate fecal coliform decay based on a constant, velocity and distance traveled. Fecal coliform decay in Medicine Creek from Presho to Kennebec was estimated at 62 cfu/100 ml leaving 1,938 cfu/100 ml viable colonies at Kennebec. The adjusted fecal coliform concentration was used along with fecal coliform concentration at Kennebec to develop the WLA for Medicine Creek.

The load allocation for Medicine Creek was calculated using assessment water quality data and was as follows. With the fecal coliform standard in effect from May through September (fecal season), the average assessment fecal coliform concentration during this period was calculated/estimated to be 1,811 colonies/100 ml (cfu/100 ml) based on 32 samples (Table 12). The total hydrologic load during the fecal season (90,379,356 ft^3) was calculated using the

FLUX model. The initial fecal coliform load for Medicine Creek during the fecal season was 4.64×10^{13} cfu/100 ml. Based on the fecal coliform violation rate, the average fecal coliform concentration needs to be 16 percent to meet the TMDL; however, with no realistic load reduction from the WLA an additional 2.3 percent reduction is needed in the LA (18.3 percent total reduction) to reach an overall fecal coliform reduction and reach the assigned TMDL. The average fecal coliform load needs to be reduced by an estimated 331 cfu/100 ml to 1,480 cfu/100 ml. The fecal coliform reduction loading per fecal season was estimated to be 3.79×10^{13} cfu/100 ml (Equation 7). The difference between the initial fecal load and the reduced fecal load (8.47×10^{12} cfu/100 ml) was used to determine, on average, fecal coliform waste from an estimated 1,793 animals needs to be reduced to meet the TMDL (Equation 8).

The fecal coliform TMDL for Medicine Creek at MCT-13 is to reduce the calculated current fecal season load allocation to 3.79×10^{13} cfu/fecal season or approximately 18.3 percent producing a fecal coliform TMDL of 3.89×10^{13} cfu/fecal season (an approximate overall reduction of 16 percent) with an implicit MOS (Table 52).

Only two violations out of a total of 117 dissolved oxygen samples were recorded since data collection began in 1999 and is not considered a problem in Medicine Creek. One parameter, pH, did not violate water quality standards during the assessment; however, four WQM samples did violate pH standards for a warmwater marginal fish life propagation water with an overall violation percentage of 3.4 percent (4 violations out of 116 total samples). Based on this data, pH was not considered a problem in Medicine Creek

Medicine Creek was monitored for tributary loading from April 2000 through May 2001. Approximately 19,701 acre-feet of water flowed out of Medicine Creek at Kennebec, South Dakota with an additional 4,732 acre-feet flowing out of the Byre Lake watershed entering Medicine Creek below the last monitored tributary site (MCT-13). Total flow from the gauged portion of the watershed (310,534 acres) was 24,433 acre-feet in 2000 and 2001. The export coefficient (water delivered per acre) for the Medicine Creek watershed was 0.079 acre-foot. Peak hydrologic load for the watershed occurred in the spring of 2001. Approximately 81.2 percent of the total hydrologic load delivered to Medicine Creek was delivered in the spring of 2001 (13 out of 16 Monitoring sites).

Watershed assessment with additional WQM data violated TSS water quality standards. Current data (FLUX modeling) indicate increased sediment loading from particular areas (sub-watersheds in Medicine Creek (Table 25). AnnAGNPS modeling identified priority areas and critical cells within the watershed for mitigation (treatment). Priority areas and critical cells were listed in Appendix C. All watershed nutrient parameters eventually affect Medicine Creek concentrations and in some watershed (Grouse Creek, Brakke Creek and Nail Creek) in-lake TSI so reductions in any or all of these parameters may lower sediment loading in Medicine Creek and in-lake TSI values in Byre Lake, Brakke Dam and Fate Dam.

MCT-1A had the highest total nitrogen-to-total phosphorus ratios during the assessment project, 2000 through 2001. In tributaries to Medicine Creek, total nitrogen-to-total phosphorus ratios were considered to be nitrogen limited while mainstem Medicine Creek was considered phosphorus limited based on a 16:1 ratio. Phosphorus limitation was especially prevalent in the upper portion of the watershed (MCT-1, MCT-1A and MCT-2) and was attributed to naturally occurring high nitrate-nitrite concentrations originating from Pierre Shale soils and groundwater seeps.

Tributary Recommendations

Tributary recommendations are based on Best Management Practices (BMPs) and best professional judgment. All reductions were modeled using water quality and/or AnnAGNPS data collected during this study. Reduction percentages given in Table 49 are the expected percent reduction in delivered sediment and nutrients in Medicine Creek based on 2000 and 2001 loading and AnnAGNPS data. Total acreage and total percentage of the watershed by priority ranking for sediment, nitrogen and phosphorus critical cells are provided in Table 50.

Table 48. AnnAGNPS modeled overall BMP reduction percentages for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004.

	Sediment		Nitrogen		Phosphorus	
Best Management Practice	**Reduction (tons/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**
Fertilizer Reduction	0.000	0.0	0.002	0.74	0.054	1.47
Grazing Management Reduction	0.001	20.0	0.028	10.29	0.020	0.54
Conservation Tillage Reduction	0.001	20.0	0.002	0.74	0.002	0.05
Buffer Strips Reduction	0.0005	10.0	0.002	0.74	0.000	0.0
Feedlot Reductions	0.000	0.0	0.000	0.0	0.000	0.0
Estimated Overall Reduction	**0.0025**	**-**	**0.034**	**-**	**0.074**	**-**

Table 49. Critical cell acreage by parameter and priority ranking for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2004.

	Sediment		Nitrogen		Phosphorus	
Priority Ranking	**Acres**	**Percentage of the watershed**	**Acres**	**Percentage of the watershed**	**Acres**	**Percentage of the watershed**
1	3,673	0.9	3,724	0.9	9,542	2.4
2	5,780	1.5	22,107	5.7	2,415	0.6
3	32,184	8.3	22,203	5.7	16,519	4.2
Total	41,637	10.7	48,034	12.3	28,476	7.3

Additional BMPs (streambank stabilization, conversion of highly erodible land to grass, riparian improvement, etc.) should be considered and implemented in the Medicine Creek watershed to further reduce sediment, nutrient and fecal coliform loads to Medicine Creek, Fate Dam, Brakke Dam and Byre Lake and are represented in the TMDL calculations as part of the implicit margin of safety (MOS). Implementing any additional BMPs will help ensure TMDL attainability in the Medicine Creek watershed.

Based on AnnAGNPS modeling, the proposed load reduction rate for TSS (10.0 percent) may be attainable (Appendix C). Attainable TSS load reduction percentages estimated by AnnAGNPS were modeled using the FLUX program to calculate the appropriate TSS LA for Medicine Creek. Because most violations occurred during high flow events, the realized modeled reduction percentage (20.1 percent) was greater than the initial modeled reduction (10 percent). The TSS TMDL for Medicine Creek is to reduce the current annual load allocation to 20,164,594 kg/yr or approximately 20.1 percent producing a TSS TMDL of 20,172,490 kg/year (Table 51) This TMDL 20,172,490 kg/year translates into a 10 percent reduction in the violation rate for TSS (263 mg/L for any one grab sample) and should meet the TSS standard for warmwater marginal fish life propagation water.

Data analysis indicated that all TSS standard violations occurred during extremely high runoff events (Table 10 and Figure 37). Potential BMP considerations for TSS load reductions may include reduced tillage (no-till), buffer strips and grazing management improvements to priority 1 and 2 critical sediment cells, especially ones near major tributaries to Medicine Creek and in Medicine Creek proper. Increasing the width and increasing vegetative composition of the riparian zone will improve sediment and nutrient filtering further reducing TSS concentrations, especially during high flows. In-stream improvements such as streambank stabilization, flow modification (diversion) structures and managing livestock in the riparian zone (managed riparian grazing, alternative water sources, limiting livestock direct access to the stream reducing bank failures and erosion, etc.).

AnnAGNPS feedlot and SD DENR feedlot rating program also indicated an 18.3 percent reduction in average delivered fecal coliform (cfu/100 ml/animal) may be attainable in Medicine Creek. The fecal coliform TMDL for Medicine Creek was to reduce the calculated current fecal season load allocation to 3.79×10^{13} cfu/fecal season or approximately 18.3 percent producing a fecal coliform TMDL of 3.89×10^{13} cfu/fecal season (an approximate overall reduction of 16 percent) with an implicit MOS (Table 52). The recommended overall fecal coliform reduction based on waste reduction from an estimated 1,793 animals will be needed to meet the TMDL. This TMDL (3.89×10^{13} cfu/fecal season (May 1 through September 30)) translates into a 16 percent reduction in the violation rate for fecal coliform ($\leq$ 2,000 cfu/100 ml for any one grab sample) and should meet the fecal coliform standard for limited contact recreation waters.

Many BMPs that reduce sediment loading (TSS) will also reduce fecal coliform loading, particularly buffer (filter) strips, grazing management, width and structure of vegetation and livestock management in the riparian zone. Fecal coliform data indicated that most violations from May through September in mainstem Medicine Creek occurred during low flow (Table 12). This suggests that livestock/wildlife utilize the riparian zone during low flow where conditions preclude increased fecal coliform transport within the stream and delivery from tributaries to mainstem Medicine Creek. Other fecal coliform BMPs to consider are nutrient management and control structures in modeled feeding areas (AnnAGNPS and SD DENR rating) which may reduce sediment, nutrient and fecal coliform loading to Medicine Creek.

All appropriate BMPs that reduce sediment, nutrients and fecal coliform loading to help meet the TSS and fecal coliform TMDLs for Medicine Creek should be seriously considered and implemented during the upcoming Medicine Creek implementation project (Table 50, Table 51 and Table 52).

Table 50. Total suspended solids and fecal coliform bacteria TMDL target loading for Medicine Creek, Lyman County, South Dakota from 2000 through 2001.

Parameter	Best Management Practice	Margin of Safety	TMDL[1] Target	TMDL Goal
Total Suspended Solids	Tributary BMPs	Implicit (conservative estimations)	≤ 263 mg/L grab sample (20,172,490 kg/year)	20.1 percent reduction in TSS (5,053,480 kg/year)
Fecal Coliform Bacteria	Tributary BMPs	Implicit (conservative estimations)	≤ 2,000 cfu/100 ml grab sample ($3.89x10^{13}$ cfu/fecal season)	18.3 percent reduction in average fecal coliform (7.50 cfu/fecal season)

[1] = Calculated based on 2000 and 2001tributary loading/concentration data

Table 51. Total suspended solids TMDL equation for Medicine Creek, Lyman and Jones Counties, South Dakota based on 2000 through 2001 data.

Component	Maximum Load
Waste Load Allocation (WLA):	7,896 (kg/yr)
+ **Load Allocation (LA):**	20,164,594 (kg/yr)
+ **Margin of Safety:**	Implicit
TMDL[1]	**20,172,490 (kg/yr)**

[1] = Represents a total suspended solids tributary load reduction of approximately 10.0 percent to realize a 20.1 percent reduction, based on flow duration estimated AnnAGNPS BMP attainability.

Table 52. Fecal Coliform TMDL equation (May 1 through September 30) for Medicine Creek, Lyman and Jones Counties, South Dakota based on 2000 through 2001 data.

Component	Maximum Load [2]
Waste Load Allocation (WLA):	$1.04x10^{12}$ (cfu/fecal season)
+ **Load Allocation (LA)**	$3.79x10^{13}$ (cfu/fecal season)
+ **Margin of Safety:**	Implicit
TMDL[1]	**$3.89x10^{13}$ (cfu/fecal season)**

[1] = Represents a fecal coliform load reduction of approximately 18.3 percent to realize a 16 percent reduction, based on overall watershed assessment/WQS fecal coliform violation percentage.
[2] = Fecal season = May 1 through September 30

4.0 Public Involvement and Coordination

Public involvement and coordination were the responsibility of American Creek Conservation District. As local sponsor for the project, they were responsible for issuing press releases and/or news bulletins. The project was discussed at monthly meetings of the American Creek

Conservation District Board, which is also a public setting where the public is invited to attend. The project was also discussed at Lyman and Jones County Commission meetings.

The American Creek County Conservation District was the appropriate lead project sponsor for this project. The Conservation District was important to this project because of its working relationship with the stakeholders within the watershed.

4.1 State Agencies

Because the South Dakota Department of Environment and Natural Resources (SD DENR) is the statewide pollution control agency, it was the appropriate lead state agency for this project. SD DENR is responsible for tracking Section 319 funds and state and local match for federal funding. The Department (SD DENR) is also responsible for coordination and data collection for all assessment and implementation projects throughout the State of South Dakota.

South Dakota Department of Agriculture (SD DOA) provided conservation commission funds for this project.

South Dakota Game, Fish and Parks (SD GF&P) provided current and long-term fisheries data, reports and endangered species list (Heritage List) for Medicine Creek which includes the Medicine Creek watershed. SD GF&P should be contacted and consulted during the planning and implementation phases of this project.

4.2 Federal Agencies

US Department of Agriculture Natural Resources Conservation Service (NRCS) provided office space and technical assistance for the project. NRCS is the contact for local landowners involved with conservation plans and practices. NRCS needs to be involved up front during all phases of the implementation process.

The United States Environmental Protection Agency (US EPA) provided financial assistance for the project. The US EPA provided $101,796 of Section 319 funds to cover project costs for the Medicine Creek watershed assessment in which the Medicine Creek watershed was assessed. EPA will also review and approve this assessment and TMDL.

The United States Fish and Wildlife Service (US FWS) did not provide financial or technical assistance during the assessment project. However, they should be contacted prior to the implementation project regarding their role in the implementation of the TMDLs and the potential impact on any endangered species (consultation process).

4.3 Local Governments, Industry, Environmental, and Other Groups; Public-at-Large

The American Creek County Conservation District within the Medicine Creek watershed took a leading role in the planning and implementation of this project. This was evident during the assessment phase and becomes more important during the implementation phase when conservation practices need to be coordinated and implemented with local landowners.

The Lower Brule Sioux Tribe (LBST) assessed Lower Medicine Creek in 2004 (Tetra Tech 2004) and has recently developed a Management Program Plan for the Lower Brule Sioux Reservation (Tetra Tech 2005). LBST was visited by SD DENR and reviewed results of the assessment, received a draft copy of the upstream assessment and TMDLs and were invited to final presentation. The Tribal Environmental Office was interested in working with the American Creek Conservation District during the implementation to coordinate BMP practices.

4.4 Other Sources of Funds

The Medicine Creek Watershed Assessment project, which included Medicine Creek, was funded with Section 319 and local funds. Conservation Commission funds along with funds from Lyman and Jones Counties were also secured for this project.

Funding Category	Source	Total
EPA Section 319 Funds	US EPA	$101,796
Conservation Commission	State	$47,864
Counties	Local	$20,000
Total Budget		**$169,660**

5.0 Aspects of the Project That Did Not Work Well

After the project implementation plan (PIP) was approved the funding was not released until early June 2000 which resulted in a setback for the data collection phase of this project. Fortunately, there was enough funding at the end of the first year so that the water quality data could be collected the following spring (2001). This delay could have been avoided had the funding been released in early March of 2000. The deadlines identified in the objectives/tasks and the milestone schedule would have had an increased chance of being met.

Another aspect of the project that provided a time delay was that AGNPS modeling was outlined as the watershed model; however, after the project was started a decision was made to change the watershed model from AGNPS version 3.65 to an updated annualized version (AnnAGNPS). This change required different data requirements and a steep learning curve to transition from AGNPS to AnnAGNPS. This increased the modeling and analysis time required for relating AnnAGNPS data to water quality monitoring data. However, this change increased resolution and identification of critical cells within the Medicine Creek watershed.

6.0 Future Activity Recommendations

The Medicine Creek watershed is an estimated 157,860 ha (390,072 acres) in size. This assessment project documented priority and critical areas for erosion (sediment), total nitrogen and total phosphorus in the watershed (Appendix C). As indicated in the report, certain areas in the Medicine Creek watershed have been identified as areas of concern. Implementation efforts should be undertaken to implement/install BMPs in critical areas and along riparian zones in the Medicine Creek watershed to improve overall water quality.

Assessment water quality data, AnnAGNPS, SD DENR feeding area rating and FLUX modeling show recommended load reductions for TSS (20.1 percent) and fecal coliform (18.3 percent) can be met. These recommended load reductions should meet assigned TMDLs (fecal coliform TMDL of $3.89x10^{13}$ cfu/fecal season and TSS TMDL of 20,172,490 kg/year) for Medicine Creek.

Fecal coliform data indicated that most violations from May through September in mainstem Medicine Creek occurred during low flow (Table 12). It is recommended that when fecal coliform samples collected from implementation and or WQM monitoring exceed the 2,000 cfu/100 ml beneficial use standard, the sample should be further analyzed using PGE (Pulse-Gel Electrophoresis) for DNA source tracking analysis. If during low flows the samples come back as “other” (neither human nor cattle), then most likely the source would be from wildlife.

An implementation project will be initiated in the spring (2005) to reduce sediment, total nitrogen and total phosphorus loading to meet the TMDL set for Medicine Creek (TSS, 20,172,490 kg/year and $3.89x10^{13}$ cfu/fecal season (May 1 through September 30) for fecal coliform), Fate Dam/Nail Creek (total phosphorus, 2,769 kg/year), Brakke Dam/Brakke Creek (total phosphorus, 501 kg/year) and Byre Lake (total phosphorus, 7,550 kg/year). Critical cells by priority ranking are outlined in Appendix C for Medicine Creek, Smith 2004a for Fate Dam/Nail Creek, Smith 2004 for Brakke Dam/Brakke Creek and Smith 2003 for Byre Lake. Implementing all modeled tributary BMPs outlined in these reports will reduce sediment, nitrogen and phosphorus loading in Medicine Creek and improve the trophic status of Fate Dam, Brakke Dam and Byre Lake.

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APPENDIX A

Medicine Creek Tributary Stage Discharge Regression Graphs and Equations from 2000 through 2001

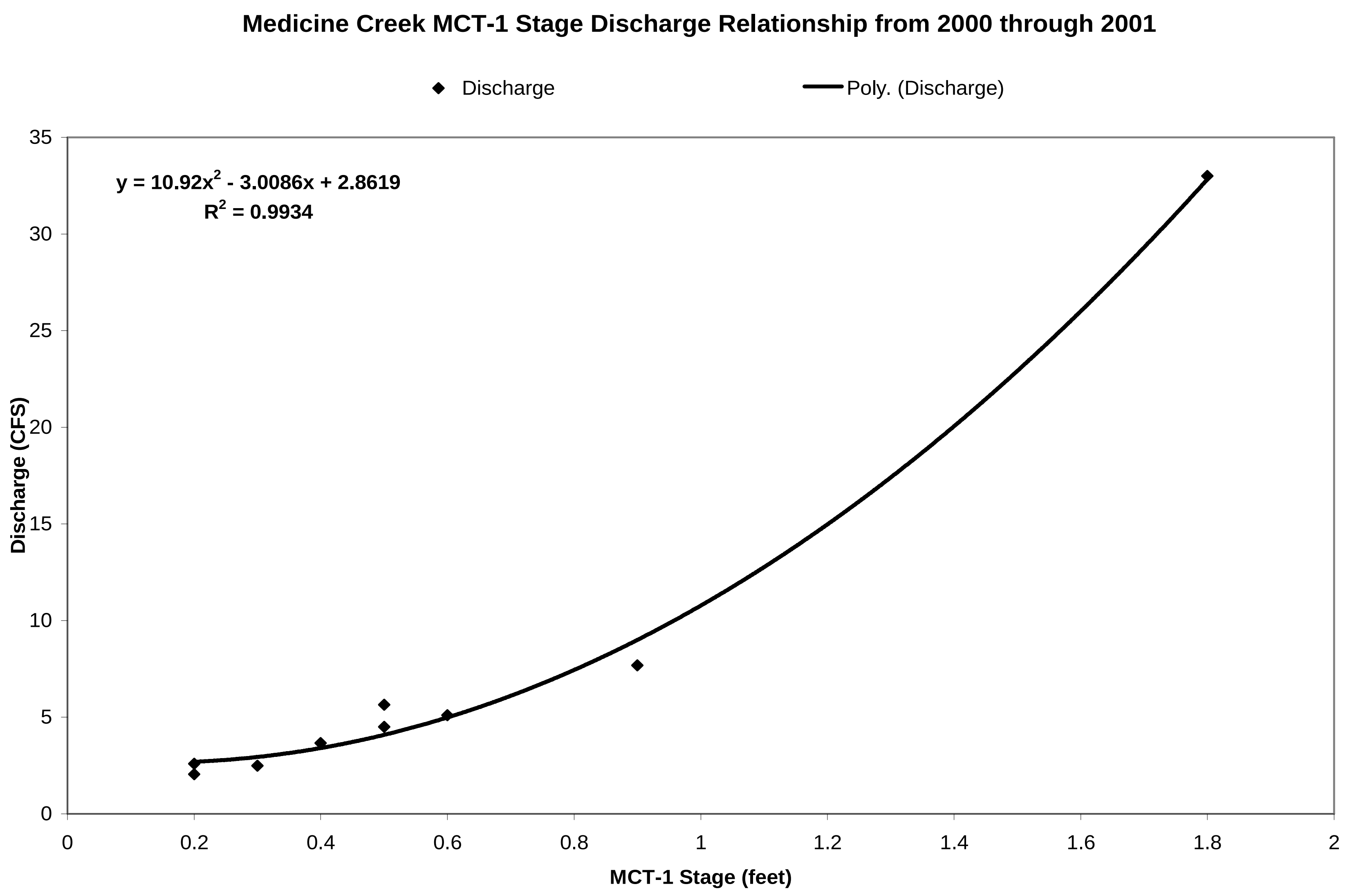


Figure A-1. Stage discharge relationship for MCT-1, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

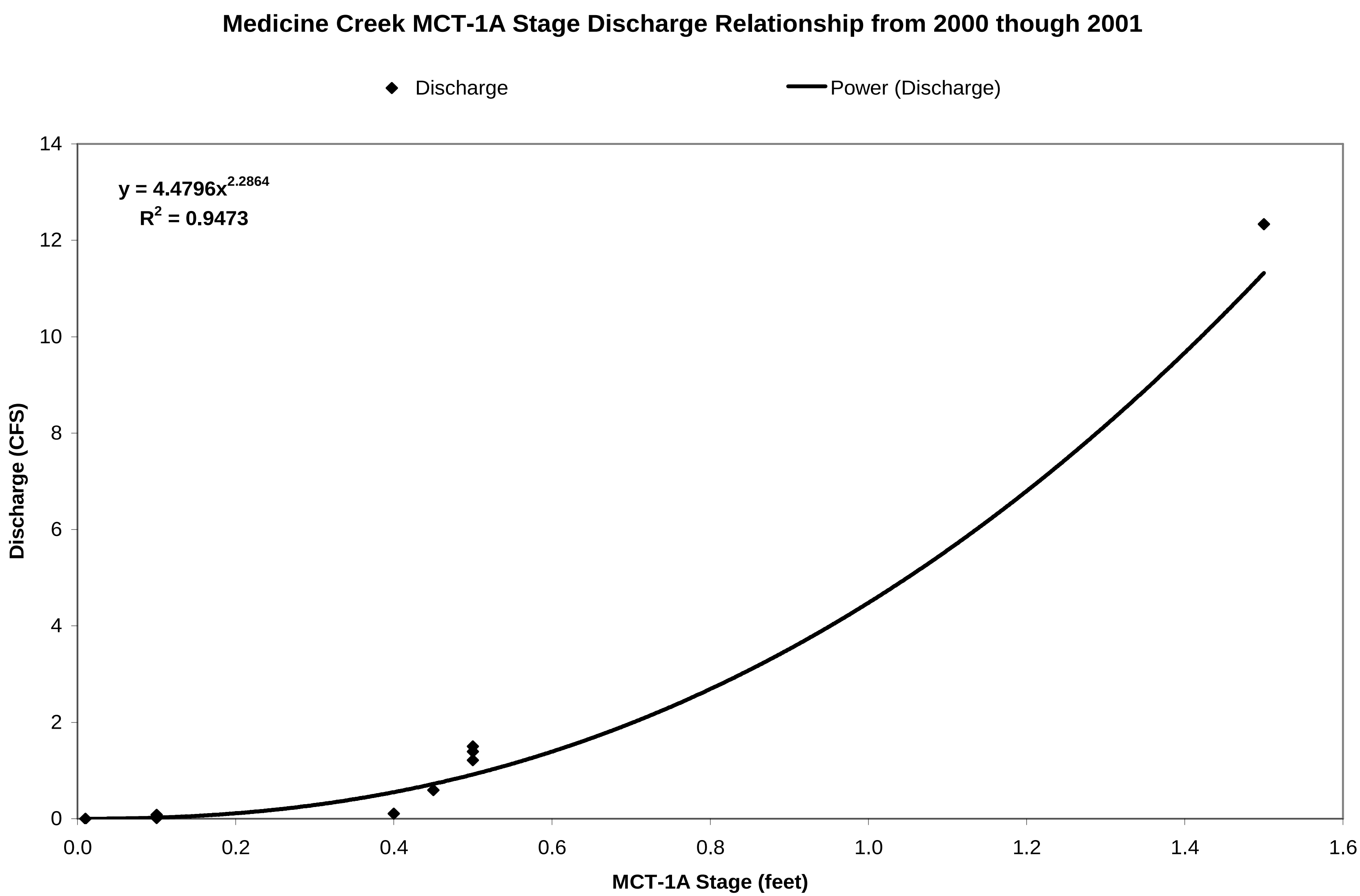


Figure A-2. Stage discharge relationship for MCT-1A, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

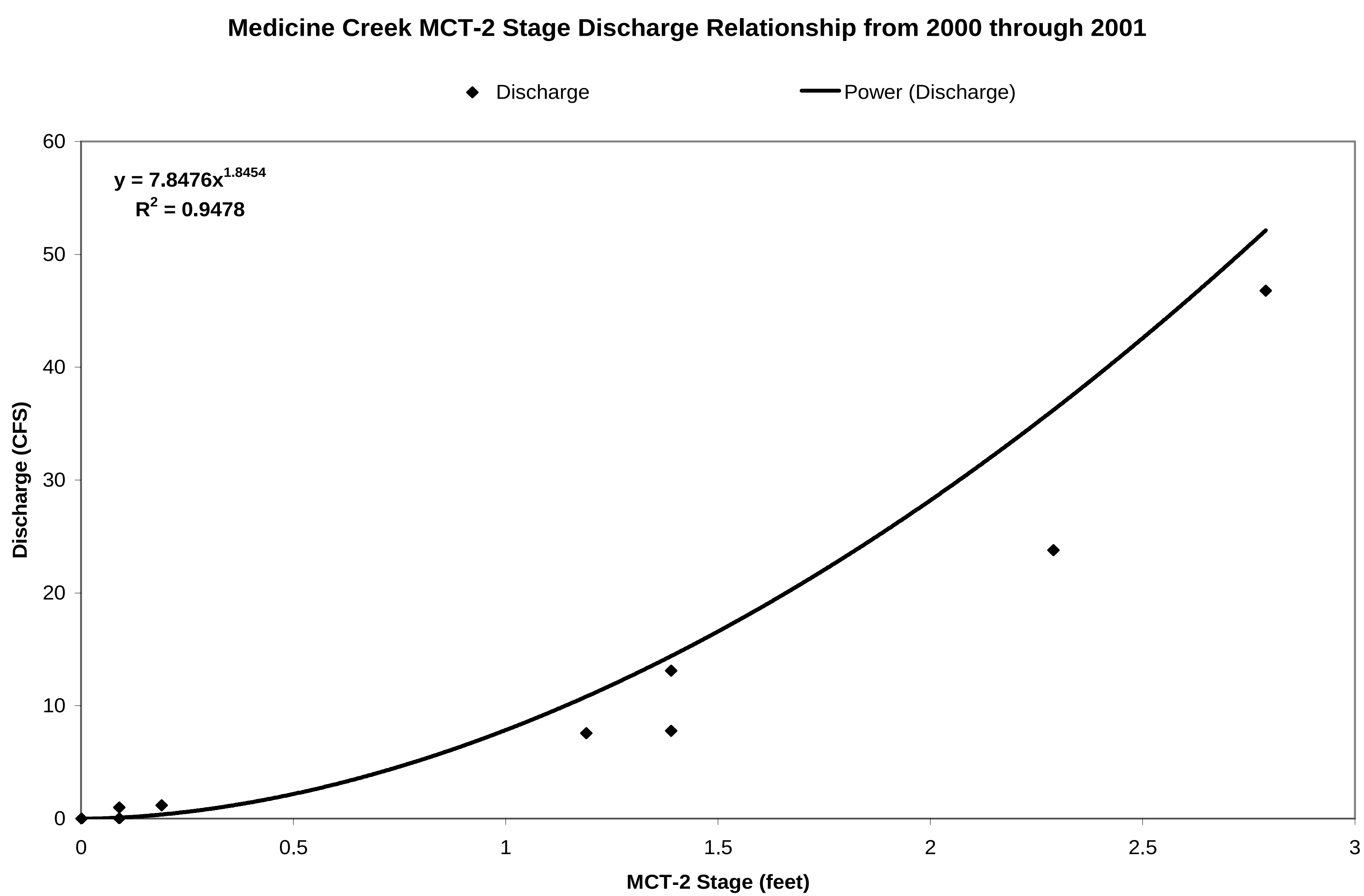


Figure A-3. Stage discharge relationship for MCT-2, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

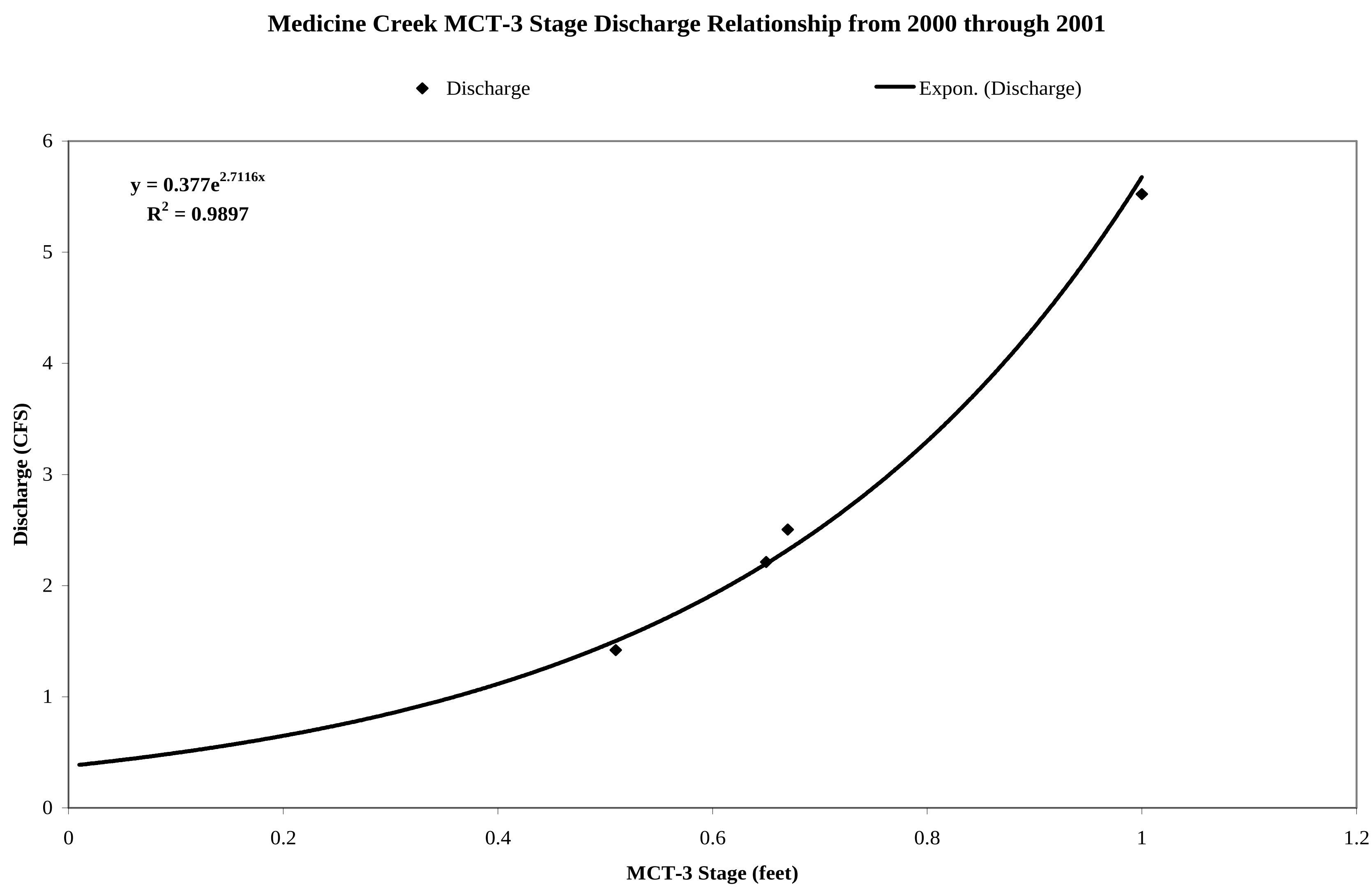


Figure A-4. Stage discharge relationship for MCT-3, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

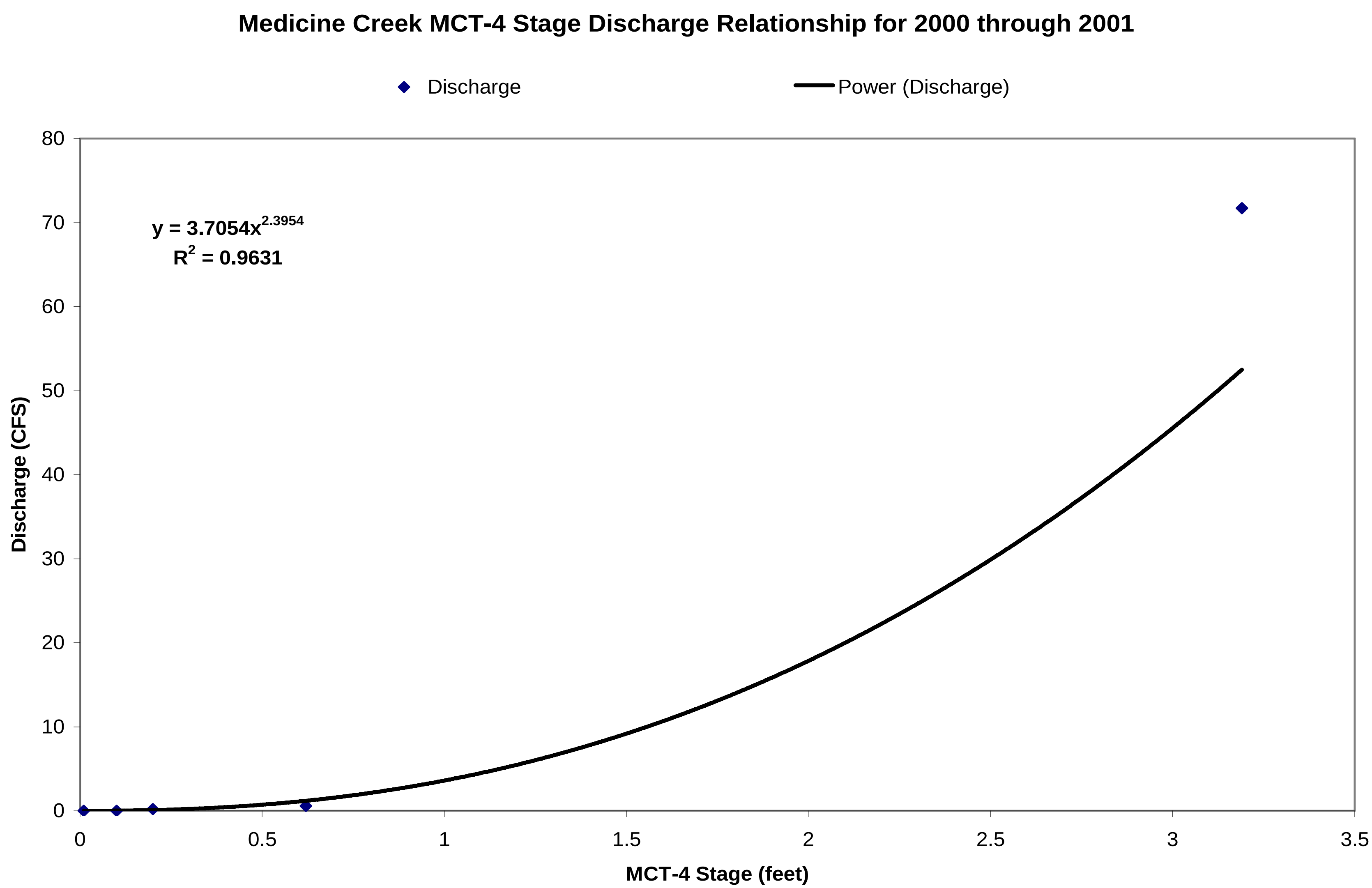


Figure A-5. Stage discharge relationship for MCT-4, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

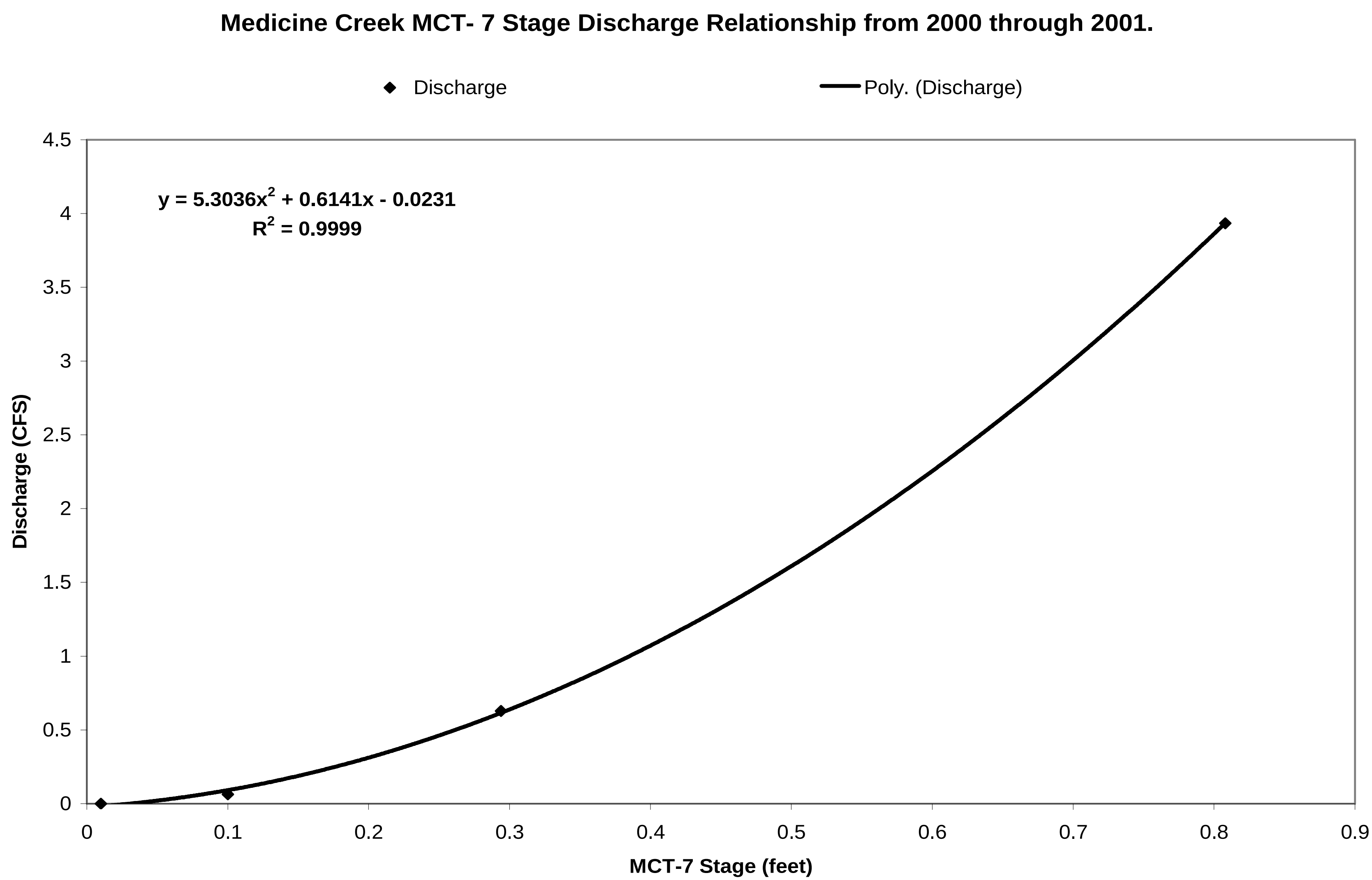


Figure A-6. Stage discharge relationship for MCT-7, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

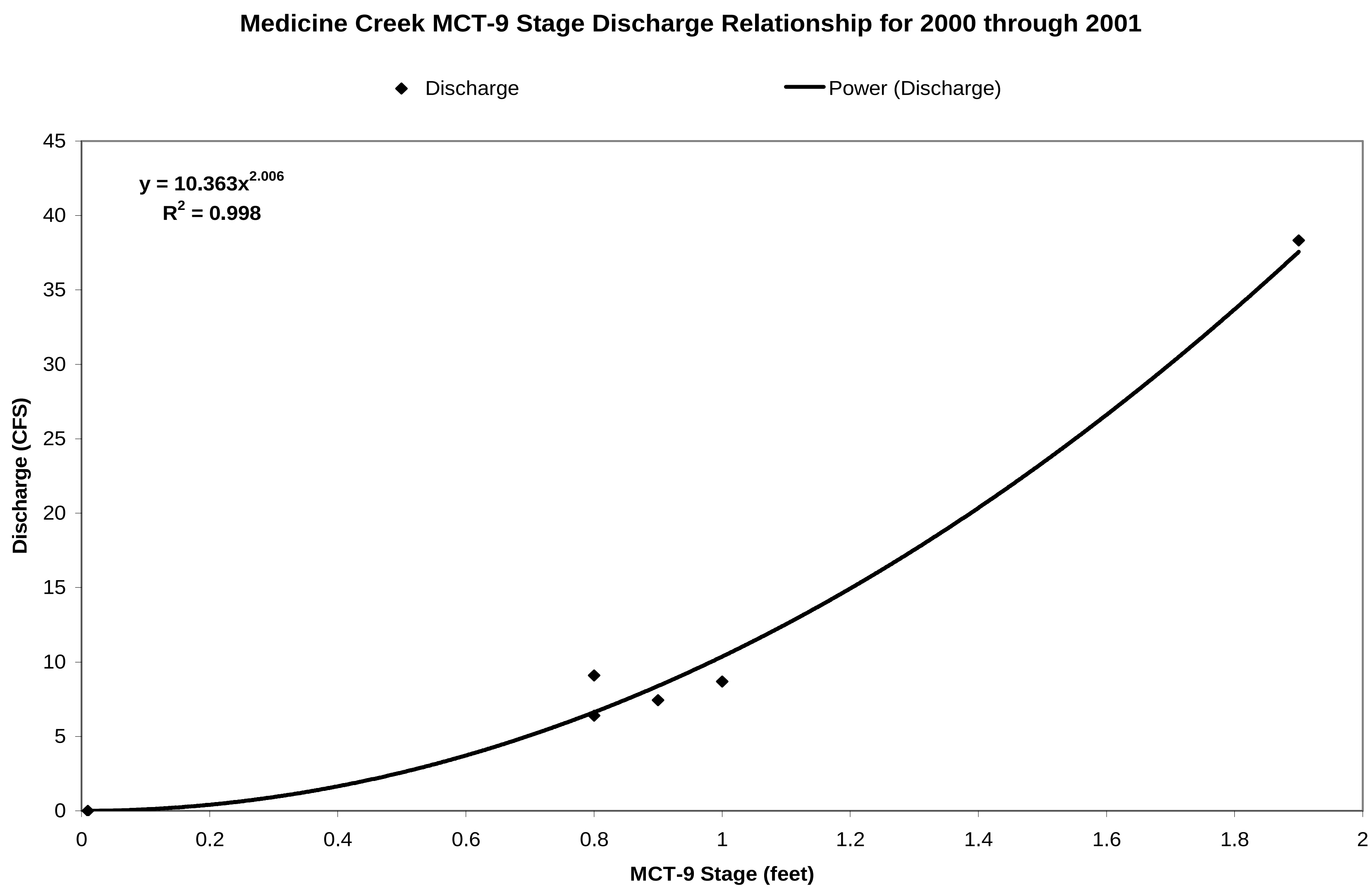


Figure A-7. Stage discharge relationship for MCT-9, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

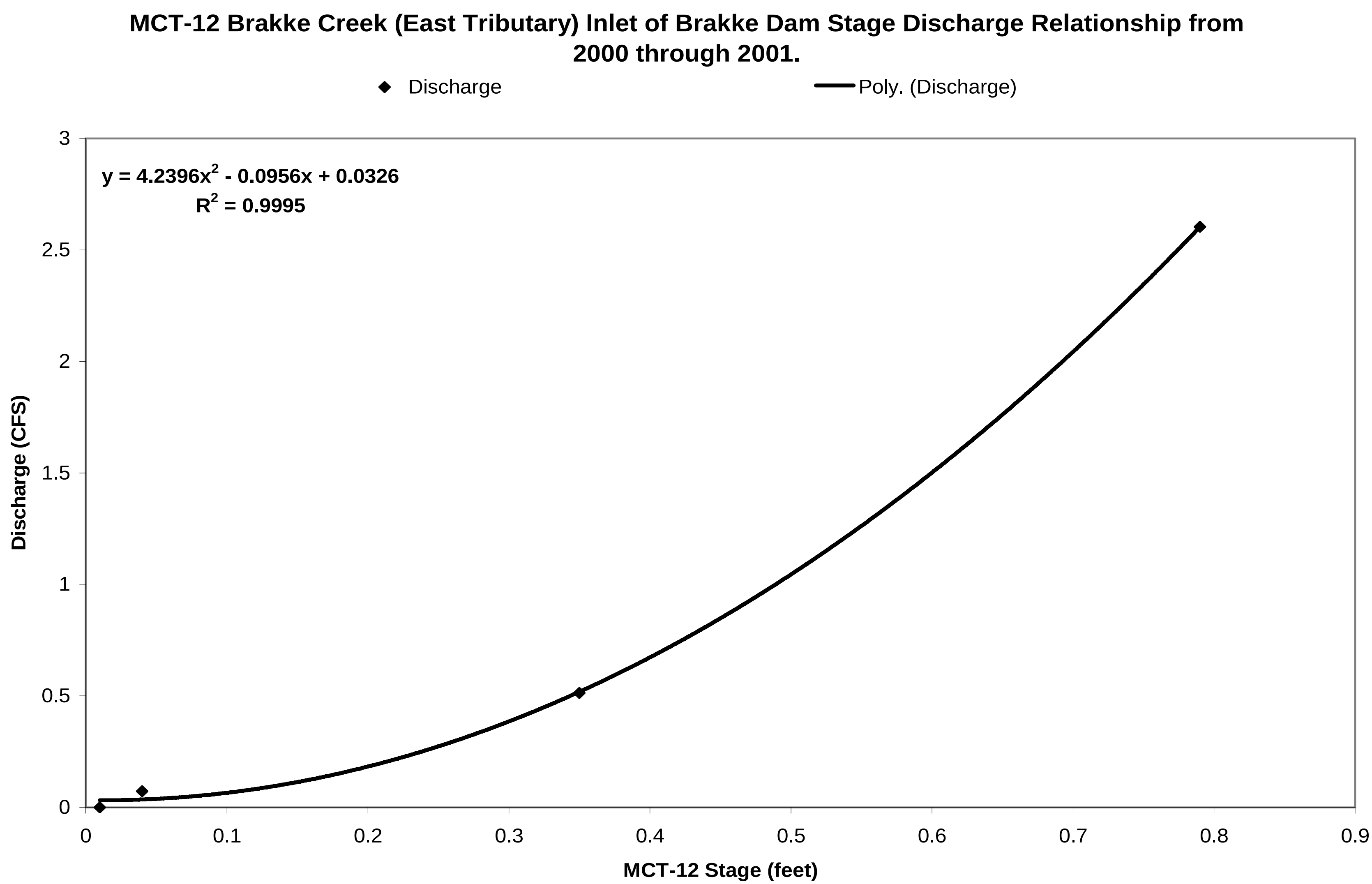


Figure A-8. Stage discharge relationship for MCT-12, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

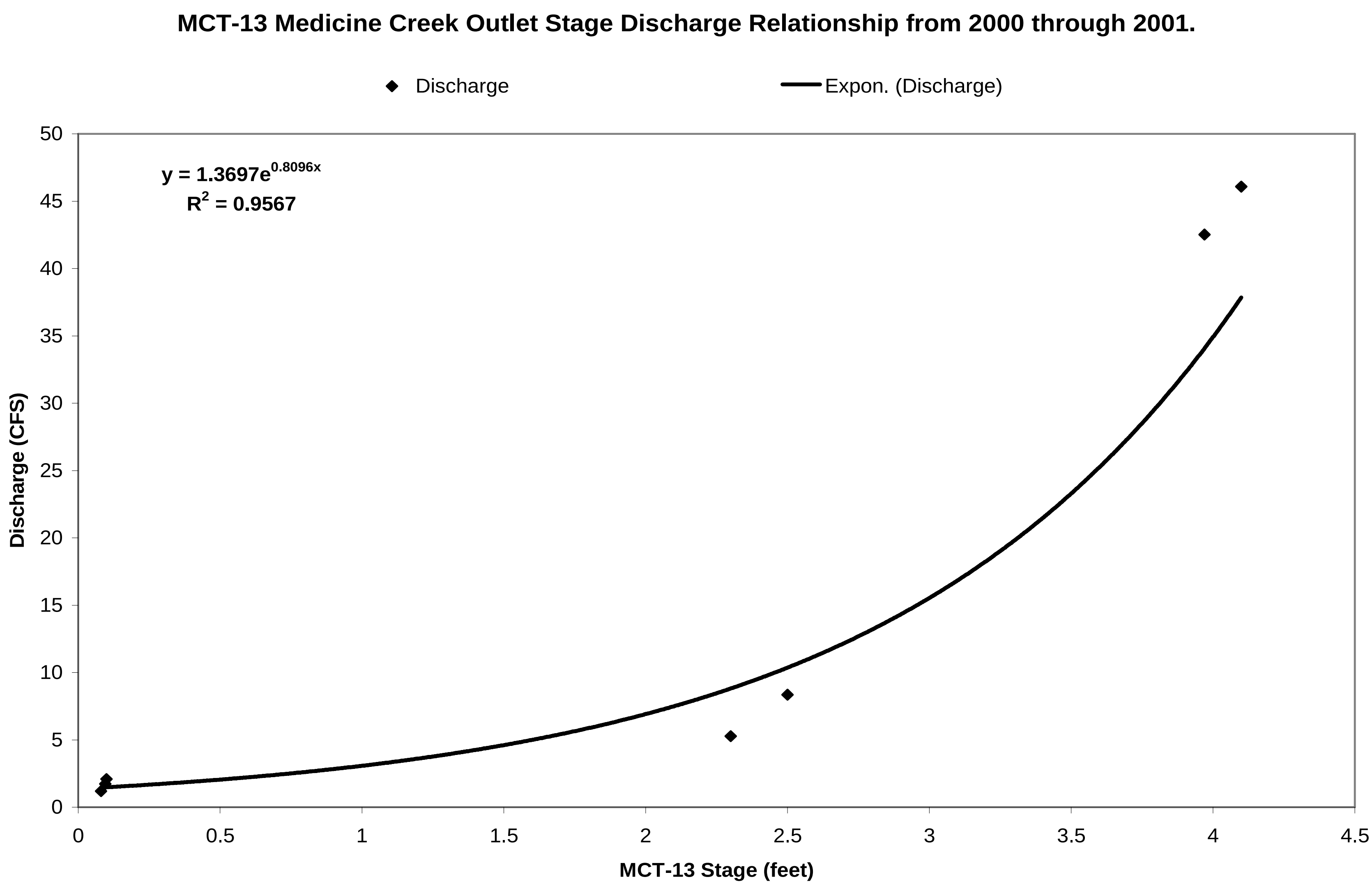


Figure A-9. Stage discharge relationship for MCT-13 (outlet), Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

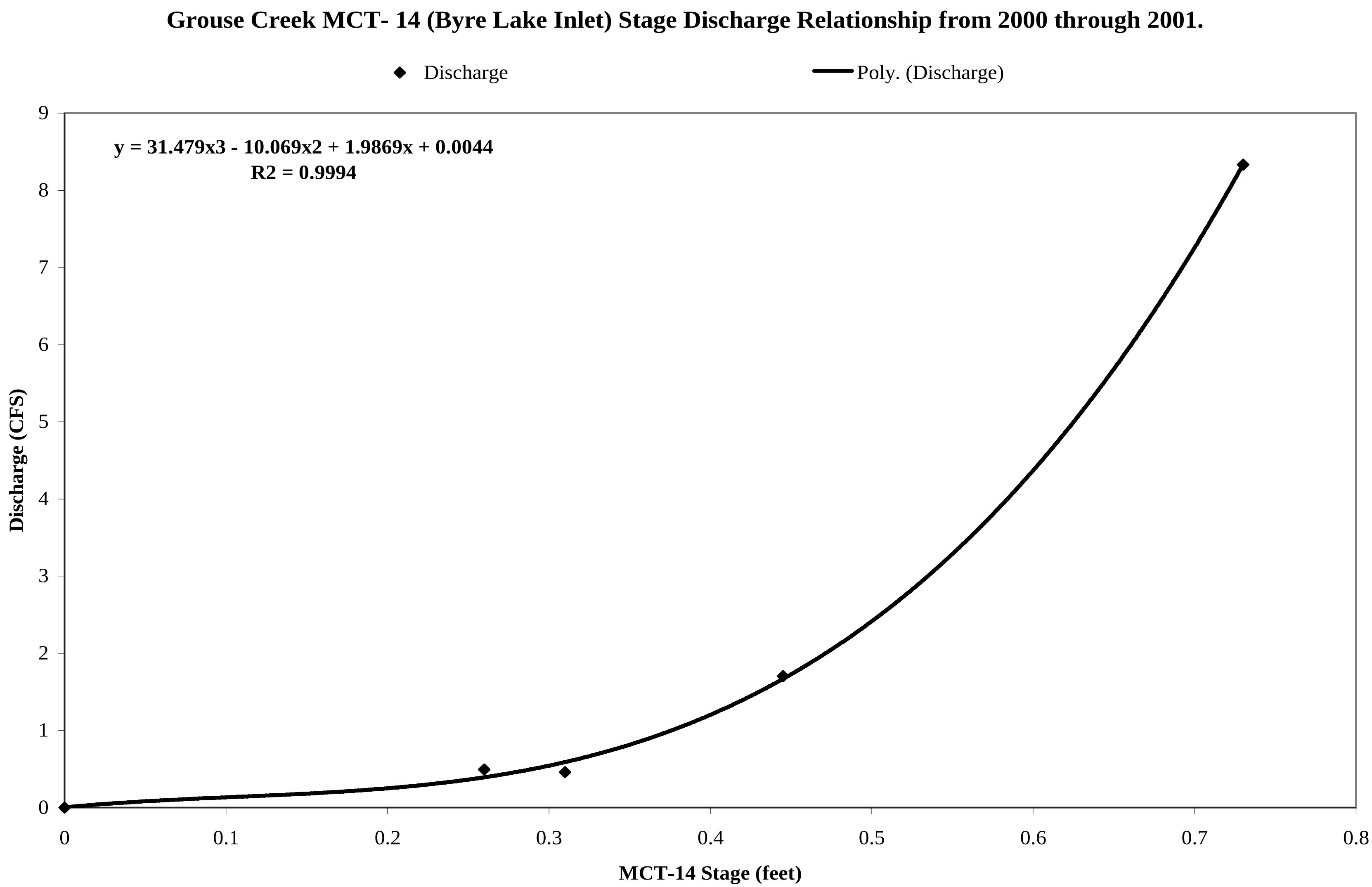


Figure A-10. Stage discharge relationship for MCT-14, Medicine Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

APPENDIX B

Multiple Comparison Matrix Tables for Total Solids on Medicine Creek from 2000 through 2001

Table B-1. Medicine Creek conductivity @ 25° C comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Conductivity (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 95) =67.67854 p =.0000

Depend.: Conductivity	MCT-1 R:74.857	MCT-1A R:67.857	MCT-2 R:66.667	MCT-3 R:28.000	MCT-4 R:27.714	MCT-5 R:31.875	MCT-6 R:31.000	MCT-7 R:38.214	MCT-8 R:26.500	MCT-9 R:72.650	MCT-10 R:12.333	MCT-11 R:12.000	MCT-12 R:8.7500	MCT-13 R:74.125	MCT-14 R:32.500	MCT-15 R:25.125
MCT-1		1.000000	1.000000	0.443856	0.165364	1.000000	1.000000	1.000000	1.000000	1.000000	0.121681	0.114325	0.015641	1.000000	0.275701	0.480022
MCT-1A	1.000000		1.000000	1.000000	0.773541	1.000000	1.000000	1.000000	1.000000	1.000000	0.421860	0.398747	0.074950	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	0.606166	1.000000	1.000000	1.000000	1.000000	1.000000	0.373606	0.352214	0.056666	1.000000	1.000000	1.000000
MCT-3	0.443856	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.372755	1.000000	1.000000	1.000000	0.200491	1.000000	1.000000
MCT-4	0.165364	0.773541	0.606166	1.000000		1.000000	1.000000	1.000000	1.000000	0.112930	1.000000	1.000000	1.000000	0.048058	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.953150	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.739686	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.372755	0.112930	1.000000	1.000000	1.000000	1.000000		0.106605	0.099794	0.010716	1.000000	0.183092	0.428272
MCT-10	0.121681	0.421860	0.373606	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.106605		1.000000	1.000000	0.061901	1.000000	1.000000
MCT-11	0.114325	0.398747	0.352214	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.099794	1.000000		1.000000	0.057719	1.000000	1.000000
MCT-12	0.015641	0.074950	0.056666	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.010716	1.000000	1.000000		0.004802	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.200491	0.048058	0.953150	1.000000	0.739686	1.000000	1.000000	0.061901	0.057719	0.004802		0.074014	0.249591
MCT-14	0.275701	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.183092	1.000000	1.000000	1.000000	0.074014		1.000000
MCT-15	0.480022	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.428272	1.000000	1.000000	1.000000	0.249591	1.000000	

Table B-2. Medicine Creek dissolved oxygen comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Dissolved Oxygen (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 114) =28.66078 p =.0178

Depend.: Dissolved Oxygen	MCT-1 R:59.900	MCT-1A R:43.083	MCT-2 R:70.700	MCT-3 R:67.500	MCT-4 R:44.313	MCT-5 R:58.100	MCT-6 R:43.167	MCT-7 R:35.438	MCT-8 R:63.500	MCT-9 R:66.429	MCT-10 R:94.667	MCT-11 R:96.500	MCT-12 R:10.250	MCT-13 R:57.929	MCT-14 R:60.111	MCT-15 R:78.250
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.239079	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.974859	0.762762	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.326212	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.974859	1.000000	1.000000		1.000000	0.099115	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.762762	1.000000	1.000000	1.000000		0.076099	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	0.239079	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.326212	0.099115	0.076099		1.000000	1.000000	0.434457
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.434457	1.000000	1.000000	

Table B-3. Medicine Creek pH comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); pH (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 114) =32.34943 p =.0058

Depend.: pH	MCT-1 R:60.100	MCT-1A R:49.864	MCT-2 R:53.773	MCT-3 R:32.083	MCT-4 R:36.500	MCT-5 R:35.200	MCT-6 R:31.333	MCT-7 R:56.188	MCT-8 R:90.500	MCT-9 R:69.393	MCT-10 R:109.17	MCT-11 R:72.000	MCT-12 R:31.500	MCT-13 R:62.615	MCT-14 R:65.278	MCT-15 R:96.625
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.705159	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.116807	1.000000	1.000000	1.000000	1.000000	0.298293
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.139765	1.000000	1.000000	1.000000	1.000000	0.356785
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	0.261849	1.000000	1.000000	1.000000	1.000000	0.672038
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	0.471138	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	0.705159	1.000000	0.116807	0.139765	0.261849	0.471138	1.000000	1.000000	1.000000		1.000000	0.251284	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.251284	1.000000		1.000000	1.000000	0.639456
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	0.298293	0.356785	0.672038	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.639456	1.000000	1.000000	

Table B-4. Medicine Creek water temperature (^oC) comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Water Temp (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 117) =16.20050 p =.3689

Depend.: Water Temp	MCT-1 R:66.318	MCT-1A R:68.750	MCT-2 R:64.227	MCT-3 R:35.833	MCT-4 R:43.750	MCT-5 R:41.100	MCT-6 R:39.667	MCT-7 R:64.688	MCT-8 R:72.500	MCT-9 R:64.143	MCT-10 R:75.000	MCT-11 R:22.000	MCT-12 R:64.000	MCT-13 R:68.857	MCT-14 R:46.833	MCT-15 R:64.875
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-5. Medicine Creek fecal coliform bacteria comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Fecal Coliform/100ml (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 116) =21.98571 p =.1082

Depend.: Fecal Coliform/100ml	MCT-1 R:60.650	MCT-1A R:74.792	MCT-2 R:70.455	MCT-3 R:58.500	MCT-4 R:53.125	MCT-5 R:40.300	MCT-6 R:62.833	MCT-7 R:49.125	MCT-8 R:36.250	MCT-9 R:67.393	MCT-10 R:37.000	MCT-11 R:22.167	MCT-12 R:76.250	MCT-13 R:70.000	MCT-14 R:36.667	MCT-15 R:34.875
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-6. Medicine Creek alkalinity comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Alkalinity (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 117) =52.30884 p =.0000

Depend.: Alkalinity	MCT-1 R:80.955	MCT-1A R:85.577	MCT-2 R:81.864	MCT-3 R:20.917	MCT-4 R:48.688	MCT-5 R:38.700	MCT-6 R:27.333	MCT-7 R:56.063	MCT-8 R:41.500	MCT-9 R:74.750	MCT-10 R:48.000	MCT-11 R:10.000	MCT-12 R:33.875	MCT-13 R:69.731	MCT-14 R:30.778	MCT-15 R:34.500
MCT-1		1.000000	1.000000	0.058480	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.158363	1.000000	1.000000	0.119688	1.000000
MCT-1A	1.000000		1.000000	0.013470	1.000000	1.000000	0.881150	1.000000	1.000000	1.000000	1.000000	0.060460	0.921445	1.000000	0.023370	1.000000
MCT-2	1.000000	1.000000		0.047937	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.137123	1.000000	1.000000	0.096663	1.000000
MCT-3	0.058480	0.013470	0.047937		1.000000	1.000000	1.000000	1.000000	1.000000	0.137218	1.000000	1.000000	1.000000	0.425598	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	0.881150	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.137218	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	0.323422	1.000000	1.000000	0.289327	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	0.158363	0.060460	0.137123	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.323422	1.000000		1.000000	0.716603	1.000000	1.000000
MCT-12	1.000000	0.921445	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.425598	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.716603	1.000000		0.970564	1.000000
MCT-14	0.119688	0.023370	0.096663	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.289327	1.000000	1.000000	1.000000	0.970564		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-7. Medicine Creek total solids concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Solids (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 117) =85.71197 p =.0000

Depend.: Total Solids	MCT-1 R:86.500	MCT-1A R:82.462	MCT-2 R:83.864	MCT-3 R:38.667	MCT-4 R:29.125	MCT-5 R:37.200	MCT-6 R:34.333	MCT-7 R:42.125	MCT-8 R:20.500	MCT-9 R:85.714	MCT-10 R:7.0000	MCT-11 R:5.6667	MCT-12 R:22.000	MCT-13 R:88.615	MCT-14 R:29.222	MCT-15 R:21.000
MCT-1		1.000000	1.000000	0.655011	0.032671	0.845196	1.000000	0.584369	1.000000	1.000000	0.038413	0.030406	0.135189	1.000000	0.020632	0.113024
MCT-1A	1.000000		1.000000	1.000000	0.055965	1.000000	1.000000	0.976122	1.000000	1.000000	0.061669	0.048976	0.218835	1.000000	0.035395	0.183488
MCT-2	1.000000	1.000000		1.000000	0.061742	1.000000	1.000000	0.970907	1.000000	1.000000	0.060366	0.048110	0.214292	1.000000	0.040588	0.180288
MCT-3	0.655011	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.536931	1.000000	1.000000	1.000000	0.341771	1.000000	1.000000
MCT-4	0.032671	0.055965	0.061742	1.000000		1.000000	1.000000	1.000000	1.000000	0.020039	1.000000	1.000000	1.000000	0.011396	1.000000	1.000000
MCT-5	0.845196	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	0.725345	1.000000	1.000000	1.000000	0.476431	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.584369	0.976122	0.970907	1.000000	1.000000	1.000000	1.000000		1.000000	0.448405	1.000000	1.000000	1.000000	0.274436	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	0.983519	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.536931	0.020039	0.725345	1.000000	0.448405	1.000000		0.031761	0.024929	0.110671	1.000000	0.011629	0.091776
MCT-10	0.038413	0.061669	0.060366	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.031761		1.000000	1.000000	0.020664	1.000000	1.000000
MCT-11	0.030406	0.048976	0.048110	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.024929	1.000000		1.000000	0.016143	1.000000	1.000000
MCT-12	0.135189	0.218835	0.214292	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.110671	1.000000	1.000000		0.071144	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.341771	0.011396	0.476431	1.000000	0.274436	0.983519	1.000000	0.020664	0.016143	0.071144		0.006467	0.058744
MCT-14	0.020632	0.035395	0.040588	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.011629	1.000000	1.000000	1.000000	0.006467		1.000000
MCT-15	0.113024	0.183488	0.180288	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.091776	1.000000	1.000000	1.000000	0.058744	1.000000	

Table B-8. Medicine Creek total dissolved solids concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Dissolved Solids (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =78.35778 p =.0000

Depend.: Total Dissolved Solids	MCT-1 R:89.091	MCT-1A R:84.846	MCT-2 R:85.909	MCT-3 R:38.333	MCT-4 R:31.375	MCT-5 R:41.800	MCT-6 R:24.333	MCT-7 R:44.750	MCT-8 R:26.750	MCT-9 R:82.750	MCT-10 R:11.333	MCT-11 R:4.6667	MCT-12 R:18.500	MCT-13 R:81.286	MCT-14 R:33.444	MCT-15 R:24.750
MCT-1		1.000000	1.000000	0.415152	0.033868	1.000000	0.438696	0.633236	1.000000	1.000000	0.057986	0.018143	0.049059	1.000000	0.035458	0.153082
MCT-1A	1.000000		1.000000	0.704337	0.060488	1.000000	0.689755	1.000000	1.000000	1.000000	0.095187	0.030335	0.083230	1.000000	0.063567	0.254679
MCT-2	1.000000	1.000000		0.736438	0.072188	1.000000	0.685962	1.000000	1.000000	1.000000	0.097999	0.031926	0.088575	1.000000	0.077304	0.263757
MCT-3	0.415152	0.704337	0.736438		1.000000	1.000000	1.000000	1.000000	1.000000	0.934876	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	0.033868	0.060488	0.072188	1.000000		1.000000	1.000000	1.000000	1.000000	0.084288	1.000000	1.000000	1.000000	0.119348	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	0.438696	0.689755	0.685962	1.000000	1.000000	1.000000		1.000000	1.000000	0.872472	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.633236	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.934876	0.084288	1.000000	0.872472	1.000000	1.000000		0.123896	0.040009	0.110805	1.000000	0.089031	0.334089
MCT-10	0.057986	0.095187	0.097999	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.123896		1.000000	1.000000	0.156946	1.000000	1.000000
MCT-11	0.018143	0.030335	0.031926	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.040009	1.000000		1.000000	0.051674	1.000000	1.000000
MCT-12	0.049059	0.083230	0.088575	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.110805	1.000000	1.000000		0.144755	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	0.119348	1.000000	1.000000	1.000000	1.000000	1.000000	0.156946	0.051674	0.144755		0.127511	0.426659
MCT-14	0.035458	0.063567	0.077304	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.089031	1.000000	1.000000	1.000000	0.127511		1.000000
MCT-15	0.153082	0.254679	0.263757	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.334089	1.000000	1.000000	1.000000	0.426659	1.000000	

Table B-9. Medicine Creek total suspended solids concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Suspended Solids (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 116) =19.42276 p =.1952

Depend.: Total Suspended Solids	MCT-1 R:64.136	MCT-1A R:47.654	MCT-2 R:46.091	MCT-3 R:52.500	MCT-4 R:44.250	MCT-5 R:44.800	MCT-6 R:76.667	MCT-7 R:66.500	MCT-8 R:38.500	MCT-9 R:78.000	MCT-10 R:38.833	MCT-11 R:47.167	MCT-12 R:79.250	MCT-13 R:74.923	MCT-14 R:48.278	MCT-15 R:49.750
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-10. Medicine Creek volatile total suspended solids concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); VTSS (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 117) =25.44399 p =.0443

Depend.: VTSS	MCT-1 R:61.136	MCT-1A R:47.038	MCT-2 R:38.955	MCT-3 R:65.000	MCT-4 R:46.813	MCT-5 R:69.200	MCT-6 R:87.000	MCT-7 R:69.000	MCT-8 R:38.000	MCT-9 R:73.464	MCT-10 R:29.500	MCT-11 R:25.667	MCT-12 R:62.250	MCT-13 R:81.923	MCT-14 R:48.278	MCT-15 R:62.125
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.238403	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	0.238403	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-11. Medicine Creek ammonia concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Ammonia (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =11.43754 p =.7210

Depend.: Ammonia	MCT-1 R:49.909	MCT-1A R:48.885	MCT-2 R:55.818	MCT-3 R:58.083	MCT-4 R:48.063	MCT-5 R:62.800	MCT-6 R:94.167	MCT-7 R:53.000	MCT-8 R:57.750	MCT-9 R:66.571	MCT-10 R:45.333	MCT-11 R:70.333	MCT-12 R:80.125	MCT-13 R:66.786	MCT-14 R:66.111	MCT-15 R:56.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-12. Medicine Creek un-ionized ammonia concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Un-ionized Ammonia (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =31.81374 p =.0068

Depend.: Un-ionized Ammonia	MCT-1 R:52.091	MCT-1A R:41.692	MCT-2 R:55.000	MCT-3 R:27.167	MCT-4 R:29.250	MCT-5 R:45.600	MCT-6 R:83.333	MCT-7 R:54.250	MCT-8 R:79.500	MCT-9 R:79.143	MCT-10 R:87.333	MCT-11 R:55.333	MCT-12 R:78.000	MCT-13 R:77.714	MCT-14 R:68.000	MCT-15 R:71.250
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.537271	1.000000	1.000000	1.000000	0.750855	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.221555	1.000000	1.000000	1.000000	0.295103	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	0.119849	1.000000	1.000000	1.000000	0.166838	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	0.537271	1.000000	0.221555	0.119849	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	0.750855	1.000000	0.295103	0.166838	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-13. Medicine Creek nitrate-nitrite concentration comparisons between sampling sites, highlighted = significantly different.

	Multiple Comparisons p values (2-tailed); Nitrate (All data for graphs.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 118) =77.79215 p =.0000															
Depend.: Nitrate	MCT-1 R:92.045	MCT-1A R:103.58	MCT-2 R:81.591	MCT-3 R:19.667	MCT-4 R:27.375	MCT-5 R:72.300	MCT-6 R:52.167	MCT-7 R:18.125	MCT-8 R:52.750	MCT-9 R:65.607	MCT-10 R:17.833	MCT-11 R:27.333	MCT-12 R:38.750	MCT-13 R:66.179	MCT-14 R:40.500	MCT-15 R:39.750
MCT-1		1.000000	1.000000	0.003671	0.005675	1.000000	1.000000	0.000397	1.000000	1.000000	0.103929	0.441565	0.914627	1.000000	0.096101	1.000000
MCT-1A	1.000000		1.000000	0.000080	0.000086	1.000000	1.000000	0.000003	1.000000	0.474451	0.010922	0.060219	0.110196	0.543986	0.002539	0.132147
MCT-2	1.000000	1.000000		0.043356	0.077702	1.000000	1.000000	0.007835	1.000000	1.000000	0.505895	1.000000	1.000000	1.000000	0.903348	1.000000
MCT-3	0.003671	0.000080	0.043356		1.000000	1.000000	1.000000	1.000000	1.000000	0.710132	1.000000	1.000000	1.000000	0.639293	1.000000	1.000000
MCT-4	0.005675	0.000086	0.077702	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	0.656321	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.000397	0.000003	0.007835	1.000000	1.000000	0.656321	1.000000		1.000000	0.208434	1.000000	1.000000	1.000000	0.183202	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	0.474451	1.000000	0.710132	1.000000	1.000000	1.000000	0.208434	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	0.103929	0.010922	0.505895	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	0.441565	0.060219	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.914627	0.110196	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	0.543986	1.000000	0.639293	1.000000	1.000000	1.000000	0.183202	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	0.096101	0.002539	0.903348	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	0.132147	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-14. Medicine Creek Total Kjeldahl Nitrogen concentration comparisons between sampling sites, highlighted = significantly different.

	Multiple Comparisons p values (2-tailed); TKN (All data for graphs.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 118) =63.14433 p =.0000															
Depend.: TKN	MCT-1 R:89.455	MCT-1A R:84.808	MCT-2 R:71.864	MCT-3 R:22.667	MCT-4 R:30.563	MCT-5 R:52.700	MCT-6 R:55.833	MCT-7 R:30.875	MCT-8 R:29.000	MCT-9 R:77.536	MCT-10 R:13.833	MCT-11 R:38.500	MCT-12 R:75.375	MCT-13 R:78.964	MCT-14 R:29.056	MCT-15 R:29.125
MCT-1		1.000000	1.000000	0.014349	0.025359	1.000000	1.000000	0.027399	1.000000	1.000000	0.082654	1.000000	1.000000	1.000000	0.010264	0.302773
MCT-1A	1.000000		1.000000	0.027916	0.050067	1.000000	1.000000	0.054054	1.000000	1.000000	0.143793	1.000000	1.000000	1.000000	0.020509	0.529752
MCT-2	1.000000	1.000000		0.552058	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.643867	1.000000
MCT-3	0.014349	0.027916	0.552058		1.000000	1.000000	1.000000	1.000000	1.000000	0.121420	1.000000	1.000000	1.000000	0.089289	1.000000	1.000000
MCT-4	0.025359	0.050067	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	0.233558	1.000000	1.000000	1.000000	0.169238	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.027399	0.054054	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	0.250332	1.000000	1.000000	1.000000	0.181722	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.121420	0.233558	1.000000	1.000000	0.250332	1.000000		0.410616	1.000000	1.000000	1.000000	0.109140	1.000000
MCT-10	0.082654	0.143793	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.410616		1.000000	1.000000	0.331821	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.089289	0.169238	1.000000	1.000000	0.181722	1.000000	1.000000	0.331821	1.000000	1.000000		0.076575	1.000000
MCT-14	0.010264	0.020509	0.643867	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.109140	1.000000	1.000000	1.000000	0.076575		1.000000
MCT-15	0.302773	0.529752	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-15. Medicine Creek organic nitrogen concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Organic Nitrogen (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =64.49066 p =.0000

Depend.: Organic Nitrogen	MCT-1 R:92.409	MCT-1A R:87.423	MCT-2 R:74.591	MCT-3 R:23.833	MCT-4 R:31.500	MCT-5 R:50.800	MCT-6 R:50.500	MCT-7 R:32.188	MCT-8 R:29.000	MCT-9 R:76.750	MCT-10 R:14.000	MCT-11 R:30.667	MCT-12 R:72.500	MCT-13 R:74.786	MCT-14 R:27.222	MCT-15 R:35.250
MCT-1		1.000000	1.000000	0.009379	0.015254	1.000000	1.000000	0.018171	1.000000	1.000000	0.051955	0.670400	1.000000	1.000000	0.002685	0.505461
MCT-1A	1.000000		1.000000	0.019869	0.032959	1.000000	1.000000	0.039171	1.000000	1.000000	0.096607	1.000000	1.000000	1.000000	0.005928	0.917092
MCT-2	1.000000	1.000000		0.415152	0.805016	1.000000	1.000000	0.916394	1.000000	1.000000	0.784754	1.000000	1.000000	1.000000	0.247696	1.000000
MCT-3	0.009379	0.019869	0.415152		1.000000	1.000000	1.000000	1.000000	1.000000	0.182771	1.000000	1.000000	1.000000	0.272271	1.000000	1.000000
MCT-4	0.015254	0.032959	0.805016	1.000000		1.000000	1.000000	1.000000	1.000000	0.340691	1.000000	1.000000	1.000000	0.516311	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.018171	0.039171	0.916394	1.000000	1.000000	1.000000	1.000000		1.000000	0.394750	1.000000	1.000000	1.000000	0.594990	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.182771	0.340691	1.000000	1.000000	0.394750	1.000000		0.472237	1.000000	1.000000	1.000000	0.084238	1.000000
MCT-10	0.051955	0.096607	0.784754	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.472237		1.000000	1.000000	0.626574	1.000000	1.000000
MCT-11	0.670400	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.272271	0.516311	1.000000	1.000000	0.594990	1.000000	1.000000	0.626574	1.000000	1.000000		0.136358	1.000000
MCT-14	0.002685	0.005928	0.247696	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.084238	1.000000	1.000000	1.000000	0.136358		1.000000
MCT-15	0.505461	0.917092	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-16. Medicine Creek inorganic nitrogen concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Inorganic Nitrogen (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =77.90825 p =.0000

Depend.: Inorganic Nitrogen	MCT-1 R:91.909	MCT-1A R:103.54	MCT-2 R:81.682	MCT-3 R:20.167	MCT-4 R:24.813	MCT-5 R:73.600	MCT-6 R:53.333	MCT-7 R:19.125	MCT-8 R:52.750	MCT-9 R:65.714	MCT-10 R:18.000	MCT-11 R:31.167	MCT-12 R:38.250	MCT-13 R:66.143	MCT-14 R:39.667	MCT-15 R:39.000
MCT-1		1.000000	1.000000	0.004308	0.002915	1.000000	1.000000	0.000560	1.000000	1.000000	0.109123	0.768767	0.866246	1.000000	0.081506	0.968673
MCT-1A	1.000000		1.000000	0.000095	0.000036	1.000000	1.000000	0.000005	1.000000	0.491357	0.011354	0.114759	0.101251	0.544341	0.001995	0.116154
MCT-2	1.000000	1.000000		0.047422	0.041576	1.000000	1.000000	0.009957	1.000000	1.000000	0.511348	1.000000	1.000000	1.000000	0.753915	1.000000
MCT-3	0.004308	0.000095	0.047422		1.000000	1.000000	1.000000	1.000000	1.000000	0.762859	1.000000	1.000000	1.000000	0.705506	1.000000	1.000000
MCT-4	0.002915	0.000036	0.041576	1.000000		1.000000	1.000000	1.000000	1.000000	0.837493	1.000000	1.000000	1.000000	0.769034	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	0.625904	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.000560	0.000005	0.009957	1.000000	1.000000	0.625904	1.000000		1.000000	0.254318	1.000000	1.000000	1.000000	0.231247	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	0.491357	1.000000	0.762859	0.837493	1.000000	1.000000	0.254318	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	0.109123	0.011354	0.511348	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	0.768767	0.114759	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.866246	0.101251	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	0.544341	1.000000	0.705506	0.769034	1.000000	1.000000	0.231247	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	0.081506	0.001995	0.753915	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	0.968673	0.116154	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-17. Medicine Creek total nitrogen concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Nitrogen (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =83.06240 p =.0000

Depend.: Total Nitrogen	MCT-1 R:92.182	MCT-1A R:103.31	MCT-2 R:81.273	MCT-3 R:16.750	MCT-4 R:25.750	MCT-5 R:71.700	MCT-6 R:52.333	MCT-7 R:19.375	MCT-8 R:51.000	MCT-9 R:69.357	MCT-10 R:13.000	MCT-11 R:27.333	MCT-12 R:47.750	MCT-13 R:68.893	MCT-14 R:36.500	MCT-15 R:28.750
MCT-1		1.000000	1.000000	0.001672	0.003507	1.000000	1.000000	0.000557	1.000000	1.000000	0.045563	0.433009	1.000000	1.000000	0.035144	0.179260
MCT-1A	1.000000		1.000000	0.000035	0.000054	1.000000	1.000000	0.000006	1.000000	1.000000	0.004514	0.063041	0.540484	1.000000	0.000801	0.016546
MCT-2	1.000000	1.000000		0.024238	0.057293	1.000000	1.000000	0.011824	1.000000	1.000000	0.261908	1.000000	1.000000	1.000000	0.430939	1.000000
MCT-3	0.001672	0.000035	0.024238		1.000000	0.957863	1.000000	1.000000	1.000000	0.194785	1.000000	1.000000	1.000000	0.214173	1.000000	1.000000
MCT-4	0.003507	0.000054	0.057293	1.000000		1.000000	1.000000	1.000000	1.000000	0.482868	1.000000	1.000000	1.000000	0.531837	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	0.957863	1.000000		1.000000	0.875208	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	0.000557	0.000006	0.011824	1.000000	1.000000	0.875208	1.000000		1.000000	0.117364	1.000000	1.000000	1.000000	0.130826	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	0.194785	0.482868	1.000000	1.000000	0.117364	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	0.045563	0.004514	0.261908	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	0.433009	0.063041	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	0.540484	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	0.214173	0.531837	1.000000	1.000000	0.130826	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	0.035144	0.000801	0.430939	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	0.179260	0.016546	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-18. Medicine Creek total phosphorus concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Phosphorus (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =37.67413 p =.0010

Depend.: Total Phosphorus	MCT-1 R:47.864	MCT-1A R:30.192	MCT-2 R:35.864	MCT-3 R:76.500	MCT-4 R:76.750	MCT-5 R:82.800	MCT-6 R:104.67	MCT-7 R:63.000	MCT-8 R:47.000	MCT-9 R:63.964	MCT-10 R:22.500	MCT-11 R:80.000	MCT-12 R:91.250	MCT-13 R:57.857	MCT-14 R:74.833	MCT-15 R:64.250
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	0.730934	0.294605	0.416759	0.081150	1.000000	1.000000	1.000000	1.000000	1.000000	0.215759	1.000000	0.314031	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	0.241814	1.000000	1.000000	1.000000	1.000000	1.000000	0.666377	1.000000	1.000000	1.000000
MCT-3	1.000000	0.730934	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	0.294605	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	0.416759	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	0.081150	0.241814	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	0.391536	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.391536	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	0.215759	0.666377	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	0.314031	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-19. Medicine Creek total dissolved phosphorus concentration comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Dissolved Phosphorus (All data for graphs.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 118) =55.52263 p =.0000

Depend.: Total Dissolved Phosphorus	MCT-1 R:40.682	MCT-1A R:30.385	MCT-2 R:33.136	MCT-3 R:79.083	MCT-4 R:88.250	MCT-5 R:94.300	MCT-6 R:106.17	MCT-7 R:66.063	MCT-8 R:60.500	MCT-9 R:53.607	MCT-10 R:47.000	MCT-11 R:91.167	MCT-12 R:96.125	MCT-13 R:41.821	MCT-14 R:85.889	MCT-15 R:71.500
MCT-1		1.000000	1.000000	1.000000	0.331870	0.439167	0.395039	1.000000	1.000000	1.000000	1.000000	1.000000	0.660574	1.000000	0.393530	1.000000
MCT-1A	1.000000		1.000000	0.470506	0.020030	0.046122	0.065131	1.000000	1.000000	1.000000	1.000000	0.664234	0.093148	1.000000	0.021922	1.000000
MCT-2	1.000000	1.000000		0.975802	0.063070	0.109950	0.125578	1.000000	1.000000	1.000000	1.000000	1.000000	0.193464	1.000000	0.072161	1.000000
MCT-3	1.000000	0.470506	0.975802		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	0.331870	0.020030	0.063070	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.263501	1.000000	1.000000
MCT-5	0.439167	0.046122	0.109950	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.388012	1.000000	1.000000
MCT-6	0.395039	0.065131	0.125578	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.373260	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	0.664234	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.660574	0.093148	0.193464	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.613179	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	0.263501	0.388012	0.373260	1.000000	1.000000	1.000000	1.000000	1.000000	0.613179		0.308176	1.000000
MCT-14	0.393530	0.021922	0.072161	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.308176		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-20. Medicine Creek alkalinity load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Alkalinity (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =17.38751 p =.2962

Depend.: Alkalinity	MCT-1 R:47.000	MCT-1A R:29.000	MCT-2 R:40.875	MCT-3 R:36.333	MCT-4 R:26.750	MCT-5 R:38.333	MCT-6 R:37.857	MCT-7 R:26.714	MCT-8 R:61.500	MCT-9 R:46.286	MCT-10 R:31.667	MCT-11 R:31.333	MCT-12 R:15.667	MCT-13 R:51.571	MCT-14 R:46.667	MCT-15 R:59.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-21. Medicine Creek total solids load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Solids (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =25.30448 p =.0460

Depend.: Total Solids	MCT-1 R:53.571	MCT-1A R:29.857	MCT-2 R:42.750	MCT-3 R:42.667	MCT-4 R:25.750	MCT-5 R:34.333	MCT-6 R:37.143	MCT-7 R:25.143	MCT-8 R:50.000	MCT-9 R:50.143	MCT-10 R:18.000	MCT-11 R:23.000	MCT-12 R:11.667	MCT-13 R:55.571	MCT-14 R:52.000	MCT-15 R:51.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.796794	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.796794	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.534726	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.534726		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-22. Medicine Creek total dissolved solids load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Dissolved Solids (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =24.12291 p =.0630

Depend.: Total Dissolved Solids	MCT-1 R:56.286	MCT-1A R:32.143	MCT-2 R:45.125	MCT-3 R:36.333	MCT-4 R:25.250	MCT-5 R:38.667	MCT-6 R:33.000	MCT-7 R:25.000	MCT-8 R:53.000	MCT-9 R:51.429	MCT-10 R:22.000	MCT-11 R:24.333	MCT-12 R:11.667	MCT-13 R:51.857	MCT-14 R:44.333	MCT-15 R:51.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.461996	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.461996	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-23. Medicine Creek total suspended solids load comparisons between sampling sites, highlighted = significantly different.

Depend.: Total Suspended Solids	Multiple Comparisons p values (2-tailed); Total Suspended Solids (MC montly and annual loading all Param.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 77) =25.91153 p =.0390															
	MCT-1 R:45.714	MCT-1A R:25.429	MCT-2 R:33.875	MCT-3 R:53.000	MCT-4 R:32.000	MCT-5 R:44.667	MCT-6 R:44.714	MCT-7 R:26.286	MCT-8 R:39.500	MCT-9 R:46.143	MCT-10 R:13.333	MCT-11 R:26.333	MCT-12 R:17.333	MCT-13 R:60.571	MCT-14 R:59.333	MCT-15 R:47.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.395391	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.497078	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.265738	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.611810	1.000000	1.000000
MCT-13	1.000000	0.395391	1.000000	1.000000	1.000000	1.000000	1.000000	0.497078	1.000000	1.000000	0.265738	1.000000	0.611810		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-24. Medicine Creek volatile total suspended solids load comparisons between sampling sites, highlighted = significantly different.

Depend.: Total Volatile Suspended Solids	Multiple Comparisons p values (2-tailed); Total Volatile Suspended Solids (MC montly and annual loading all Param.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 77) =24.27549 p =.0606															
	MCT-1 R:44.143	MCT-1A R:26.286	MCT-2 R:33.000	MCT-3 R:47.000	MCT-4 R:36.000	MCT-5 R:41.333	MCT-6 R:46.857	MCT-7 R:25.571	MCT-8 R:46.500	MCT-9 R:44.714	MCT-10 R:15.667	MCT-11 R:25.667	MCT-12 R:17.333	MCT-13 R:60.000	MCT-14 R:59.333	MCT-15 R:50.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.577488	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.478632	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.489935	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.685728	1.000000	1.000000
MCT-13	1.000000	0.577488	1.000000	1.000000	1.000000	1.000000	1.000000	0.478632	1.000000	1.000000	0.489935	1.000000	0.685728		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-25. Medicine Creek ammonia load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Ammonia (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =22.40889 p =.0975

Depend.: Ammonia	MCT-1 R:39.857	MCT-1A R:26.714	MCT-2 R:37.750	MCT-3 R:34.000	MCT-4 R:29.250	MCT-5 R:39.000	MCT-6 R:38.857	MCT-7 R:27.929	MCT-8 R:42.000	MCT-9 R:52.857	MCT-10 R:20.333	MCT-11 R:34.333	MCT-12 R:19.167	MCT-13 R:62.714	MCT-14 R:49.000	MCT-15 R:56.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.313011	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.435205	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.725628	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		0.574852	1.000000	1.000000
MCT-13	1.000000	0.313011	1.000000	1.000000	1.000000	1.000000	1.000000	0.435205	1.000000	1.000000	0.725628	1.000000	0.574852		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-26. Medicine Creek nitrate-nitrite load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Nitrate - Nitrite (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =26.11044 p =.0369

Depend.: Nitrate - Nitrite	MCT-1 R:54.571	MCT-1A R:41.571	MCT-2 R:45.500	MCT-3 R:19.000	MCT-4 R:21.750	MCT-5 R:43.333	MCT-6 R:40.714	MCT-7 R:27.714	MCT-8 R:51.500	MCT-9 R:51.143	MCT-10 R:11.667	MCT-11 R:25.000	MCT-12 R:10.333	MCT-13 R:49.000	MCT-14 R:40.667	MCT-15 R:48.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.654002	1.000000	0.499584	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.984825	1.000000	1.000000	1.000000
MCT-10	0.654002	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.499584	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.984825	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-27. Medicine Creek Total Kjeldahl Nitrogen load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Kjeldahl Nitrogen (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =18.80590 p =.2227

Depend.: Total Kjeldahl Nitrogen	MCT-1 R:47.714	MCT-1A R:29.429	MCT-2 R:39.875	MCT-3 R:33.333	MCT-4 R:30.250	MCT-5 R:36.667	MCT-6 R:39.857	MCT-7 R:26.429	MCT-8 R:55.500	MCT-9 R:47.571	MCT-10 R:19.667	MCT-11 R:30.667	MCT-12 R:18.333	MCT-13 R:55.714	MCT-14 R:46.667	MCT-15 R:56.333
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-28. Medicine Creek organic nitrogen load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Organic Nitrogen (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =19.67829 p =.1846

Depend.: Organic Nitrogen	MCT-1 R:48.286	MCT-1A R:29.286	MCT-2 R:40.125	MCT-3 R:33.667	MCT-4 R:30.500	MCT-5 R:37.000	MCT-6 R:39.857	MCT-7 R:26.000	MCT-8 R:55.000	MCT-9 R:48.571	MCT-10 R:17.333	MCT-11 R:30.333	MCT-12 R:18.333	MCT-13 R:55.571	MCT-14 R:46.667	MCT-15 R:55.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-29. Medicine Creek inorganic nitrogen load comparisons between sampling sites, highlighted = significantly different.

Depend.: Inorganic Nitrogen	Multiple Comparisons p values (2-tailed); Inorganic Nitrogen (MC montly and annual loading all Param.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 77) =25.52476 p =.0433 MCT-1 R:56.571	MCT-1A R:38.714	MCT-2 R:45.250	MCT-3 R:20.667	MCT-4 R:22.000	MCT-5 R:42.667	MCT-6 R:40.571	MCT-7 R:28.571	MCT-8 R:50.500	MCT-9 R:49.857	MCT-10 R:12.333	MCT-11 R:25.000	MCT-12 R:10.667	MCT-13 R:49.286	MCT-14 R:41.333	MCT-15 R:49.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.499584	1.000000	0.353330	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	0.499584	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.353330	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-30. Medicine Creek total nitrogen load comparisons between sampling sites, highlighted = significantly different.

Depend.: Total Nitrogen	Multiple Comparisons p values (2-tailed); Total Nitrogen (MC montly and annual loading all Param.sta) Independent (grouping) variable: Site Kruskal-Wallis test: H (15, N= 77) =23.68440 p =.0707 MCT-1 R:54.857	MCT-1A R:37.286	MCT-2 R:44.625	MCT-3 R:23.667	MCT-4 R:23.750	MCT-5 R:42.000	MCT-6 R:40.571	MCT-7 R:29.143	MCT-8 R:52.000	MCT-9 R:49.286	MCT-10 R:13.000	MCT-11 R:25.333	MCT-12 R:10.333	MCT-13 R:50.429	MCT-14 R:40.333	MCT-15 R:50.667
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.804245	1.000000	0.471144	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	0.804245	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	0.471144	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-31. Medicine Creek total phosphorus load comparisons between sampling sites, highlighted = significantly different.

Multiple Comparisons p values (2-tailed); Total Phosphorus (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =24.27228 p =.0606

Depend.: Total Phosphorus	MCT-1 R:44.000	MCT-1A R:21.786	MCT-2 R:31.188	MCT-3 R:50.667	MCT-4 R:31.625	MCT-5 R:39.667	MCT-6 R:42.857	MCT-7 R:27.429	MCT-8 R:47.500	MCT-9 R:46.429	MCT-10 R:16.167	MCT-11 R:33.333	MCT-12 R:25.000	MCT-13 R:60.000	MCT-14 R:57.333	MCT-15 R:56.000
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.167426	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	0.774521	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.542542	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	0.167426	1.000000	1.000000	1.000000	1.000000	1.000000	0.774521	1.000000	1.000000	0.542542	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

Table B-32. Medicine Creek total dissolved phosphorus load comparisons between sampling sites, highlighted = significantly different.

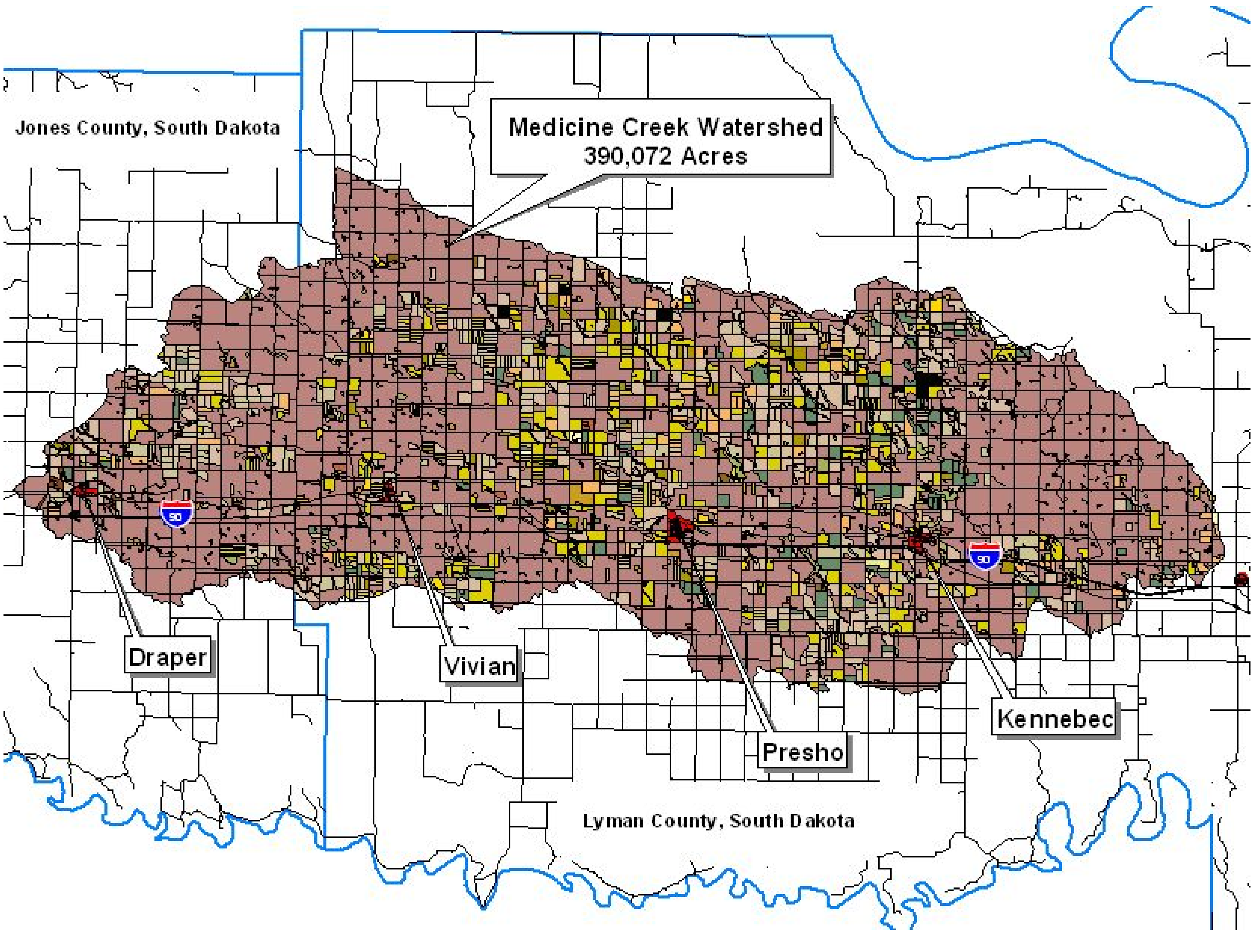
Multiple Comparisons p values (2-tailed); Total Dissolved Phosphorus (MC montly and annual loading all Param.sta)
Independent (grouping) variable: Site
Kruskal-Wallis test: H (15, N= 77) =19.78023 p =.1805

Depend.: Total Dissolved Phosphorus	MCT-1 R:34.143	MCT-1A R:21.929	MCT-2 R:32.500	MCT-3 R:42.333	MCT-4 R:35.000	MCT-5 R:47.667	MCT-6 R:43.000	MCT-7 R:31.500	MCT-8 R:52.000	MCT-9 R:45.357	MCT-10 R:16.167	MCT-11 R:38.333	MCT-12 R:32.000	MCT-13 R:57.000	MCT-14 R:52.667	MCT-15 R:60.333
MCT-1		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-1A	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.403078	1.000000	1.000000
MCT-2	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-3	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-4	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-5	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-6	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-7	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-8	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-9	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
MCT-10	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	0.980348	1.000000	1.000000
MCT-11	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000	1.000000
MCT-12	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000	1.000000	1.000000
MCT-13	1.000000	0.403078	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.980348	1.000000	1.000000		1.000000	1.000000
MCT-14	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000		1.000000
MCT-15	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	

APPENDIX C

Medicine Creek Annual Agricultural Non-Point Source Pollution Model (AnnAGNPS) Final Report

ANNUALIZED AGRICULTURAL NON-POINT SOURCE (AnnAGNPS) ANALYSIS OF MEDICINE CREEK WATERSHED, LYMAN AND JONES COUNTIES, SOUTH DAKOTA



Prepared by:
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SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
WATER RESOURCES ASSISTANCE PROGRAM

JANUARY 2005

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INTRODUCTION

Water quality is a major concern, especially in the agricultural states of the Midwestern United States. Several common water quality problems have been noted in lakes and reservoirs of the Central Plains. There have been reports of elevated plant nutrient levels, with concurrent elevations in plant biomass (Smith, 1998). Suspended solids and siltation have increased, and increases in these factors reduce light penetration, aesthetics, lake depth and volume, leading to alteration of aquatic habitats (deNoyelles et al., 1999). Water quality assessments have shown elevated levels of pesticides and other toxic chemicals (Scribner et al., 1996). Further, local and state regulatory agencies have fielded complaints regarding objectionable taste and odor conditions (e.g., KDHE, 1999). All these problems contribute to or are symptomatic of water quality degradation. However, excess nutrients and siltation, both of which result from intensive agricultural activities, are the water quality factors that contribute most to eutrophication (Carpenter et al., 1998). Eutrophication is itself a serious and widespread problem in the Midwest. According to the National Water Quality Report to Congress, 50 percent of assessed U.S. lakes and a higher percentage of reservoirs in the agriculturally dominated Midwest were considered eutrophic (USEPA, 2000).

A vital key to the development of a lake/reservoir management strategy is to identify nutrient loading that describes associated eutrophic conditions in lakes and reservoirs. Annualized Agricultural Nonpoint Source (AnnAGNPS 3.32.a. 34) is a batch-process, continuous-simulation, watershed-scale model designed for agriculturally dominated watersheds, which was developed jointly by U.S. Department of Agriculture's Agricultural Research Service and Natural Resource Conservation Service (Bosch et al., 1998; Cronshey and Theurer, 1998; Geter and Theurer, 1998; Theurer and Cronshey, 1998; Johnson et al., 2000).

AnnAGNPS requires more than 400 parameters in 34 data categories, including land use, topography, hydrology, soils, feedlot operation, field management, and climate. AnnAGNPS uses up-to-date technologies that expand the original modeling capabilities of AGNPS. For example, soil loss from each field is predicted based on the Revised Universal Soil Loss Equation (RUSLE) (Renard et al, 1997) and the sediment yield leaving each field is based on the Hydrogeomorphic Universal Soil Loss Equation (HUSLE) (Theurer and Clarke, 1991).

AnnAGNPS is an effective tool for watershed assessment. However, the complexity of modeling procedures and massive data preparation render its application tedious and time consuming. Therefore, automation of the preparation and processing of repetitive data is required. ArcView® Spatial AnnAGNPS interface is a user-friendly tool developed to assist decision-makers to conduct easier, effective watershed assessments. The Spatial AnnAGNPS interface not only assists users to extract the required soil data from the National Soil Survey Geographic Database (SSURGO) but also helps users organize input files, run the model, and visualize modeling results.

AnnAGNPS is a data-intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into cells of varying sizes based on topography. Each cell is then assigned a primary land use and soil type.

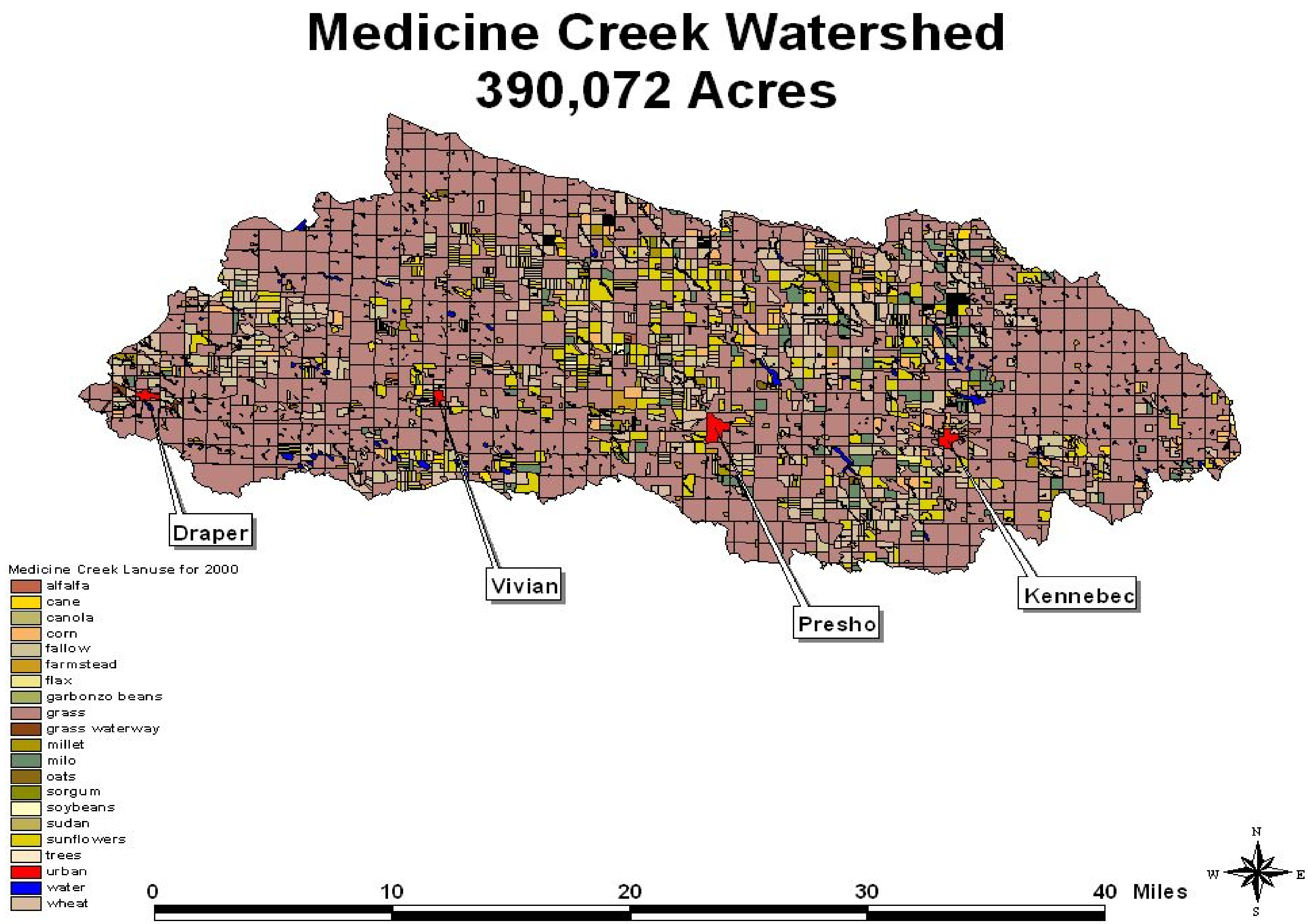

Figure C-1. Landuse in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000.

Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells with reductions in sediment and nutrient yield are calculated at the outlet to the watershed.

METHODS

The Medicine Creek watershed (Figure C-1) was modeled and analyzed using AnnAGNPS modeling program. ArcView® data layers for AnnAGNPS were acquired from various governmental agencies. Digital Elevation Model layers (DEMs) were downloaded from a United States Geological Survey website, soil layers were downloaded from a United States Department of Agricultural, Natural Resource Conservation Service (USDA-NRCS) website and digital NASIS (National Soil Information System) data were obtained from the NRCS office in Huron, South Dakota. AnnAGNPS field and feedlot data and field digitizing in ArcView® for the Medicine Creek watershed analysis was collected/performed by personnel from the American Creek Conservation District from 2001 through 2004. Field history, planting and crop rotation data was obtained from the Farm Service Agency in Kennebec. Tillage, fertilization and feedlot data for the Medicine Creek watershed was acquired through the use of stakeholder surveys. Planting dates for specific crops and tillage practices were acquired for this region using RUSLE data provided by NRCS. All AnnAGNPS data modification and entry was preformed by South Dakota Department of Environment and Natural Resources (SD DENR) Water Resources Assistance Program (WRAP).

Part of the modeling process includes the assessment of Animal Feeding Operations (AFOs) located in the watershed. This assessment was completed with the assistance of the American Creek Conservation District which provided estimates on the number of animal units and duration of use in the Medicine Creek Watershed. Thirty eight AFOs were identified in the Medicine Creek Watershed and with one being an approved but not permitted Confined Animal Feeding Operation (CAFO).

Climate/weather data from Pierre, South Dakota was used to generate simulated weather data. Model results are based on one year of climate data for initializing variables prior to 25-year watershed simulation. Simulated precipitation based on climate data ranged from 13 to 29 inches per year. Mean annual precipitation for this watershed is approximately 17 inches.

Impoundment data was obtained from ArcView® Digital Ortho Quad layers (DOQs). DOQs were used to identify and quantify impoundments greater than 10 acres. Average depths were estimated based on best professional judgment using known waterbodies of similar size. Coefficients were calculated based on surface area and depth, with an equation based on impoundment morphology.

Initial critical cells for sediment, nitrogen and phosphorus were determined using simulated cell specific runoff values (kg/acre), with threshold runoff values greater than one and two standard deviations above the mean. Sediment, nitrogen and phosphorus cells were analyzed and prioritized independently based on statistical characteristics. Cellular loading greater than two standard deviations above the mean for each category (sediment, nitrogen and phosphorus) received a priority ranking of one (1), loading cells greater than one but less than two standard deviation above the mean received a priority ranking of two (2) and cellular loading between one standard deviation and the mean received a priority three (3) ranking.

Medicine Creek was identified in the 2004 Integrated Report (SD DENR 2004) as having increased loading and assigned beneficial use water quality standards violations for conductivity and TDS (Total Dissolved Solids). During the assessment fecal coliform bacteria and TSS (Total Suspended Solids) also violated assigned beneficial use water quality standards. Modeled reductions were based on sediment critical cells only, as sediment is the main component of concern.

The existing field conditions, three-year crop rotation and fertilizer applications were modeled through AnnAGNPS to obtain initial (current) loading values at the outlet of each cell and the watershed (pounds/acre/year). Specific AnnAGNPS parameters would then be manipulated (conventional tillage converted to no-tillage, moderate phosphorus fertilization application converted to low fertilization applications, etc.) to represent specific BMPs applied to the watershed. The AnnAGNPS model was re-run with manipulated values, the modified loading values were compared to the initial values to estimate/calculate sediment and nutrient reduction percentages. All reduction percentages were developed and calculated using AnnAGNPS modeled load reductions based on best available landuse data.

Within the Medicine Creek watershed were three lakes, Byre Lake, Brakke Dam and Fate Dam requiring TMDLs (Total Maximum Daily Load) for violating ecoregion 43 TSI (Trophic State Index) standards caused by excess nutrients (phosphorus). During the Medicine Creek watershed assessment project, data was collected on these watersheds and lakes to develop separate assessment reports, AnnAGNPS reports and TMDLs. Three separate watershed assessment reports and associated TMDLs have been written and approved by the United States Environmental Protection Agency (US EPA) for these waters in the Medicine Creek watershed (Smith, 2003, Smith, 2004 and Smith, 2004a). Each report contains a separate detailed AnnAGNPS report and was run with refined critical cells and cell size based on specific watershed characteristics. Thus, Medicine Creek watershed critical cells have different counts, shapes, sizes and locations due to AnnAGNPS program characteristics, DEMs and critical cell calculations (standard deviation method). Although larger, many Medicine Creek critical cells overlap with sub-watershed specific (Byre Lake, Brakke Dam and Fate Dam) critical cells.

RESULTS AND DISCUSSION

Critical Cells

Priority critical cells for sediment, nitrogen and phosphorus for the Medicine Creek watershed based on AnnAGNPS modeling are shown spatially in Figure C-2 (sediment), Figure C-3 (nitrogen) and Figure C-4 (phosphorus). AnnAGNPS model identified approximately 41,637 acres of critical areas for sediment, or 10.7 percent of the entire Medicine Creek watershed, based on the above criteria (Table C-1). The Medicine Creek watershed has been identified as having increased TDS concentrations and specific conductance values violating assigned beneficial use water quality standards; however, AnnAGNPS does not model TDS and specific conductance parameters (SD DENR, 2002, SD DENR, 2004). During the Medicine Creek watershed assessment fecal coliform bacteria counts and TSS concentrations also violated assigned beneficial use water quality standards (assessment portion of this report).

Table C-1. Critical cell acreage by priority ranking for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota from 2000 through 2004.

	Sediment		Nitrogen		Phosphorus	
Priority Ranking	Acres	Percentage of the watershed	Acres	Percentage of the watershed	Acres	Percentage of the watershed
1	3,673	0.9	3,724	0.9	9,542	2.4
2	5,780	1.5	22,107	5.7	2,415	0.6
3	32,184	8.3	22,203	5.7	16,519	4.2
Total	41,637	10.7	48,034	12.3	28,476	7.3

Table C-1 lists sediment, nitrogen and phosphorus critical cells by acreage and priority rank for the Medicine Creek watershed.

Spatially, all critical cells (sediment, nitrogen and phosphorus) were generally evenly distributed throughout the watershed (Figure C-2, Figure C-3 and Figure C-4). Table C-1 indicates for sediment critical cells approximately 0.9 percent of the total acres in the Medicine Creek watershed were priority one, 1.5 percent of the watershed were priority two and 8.3 percent of the watershed were priority three. All priority cells should be field verified prior to BMP implementation.

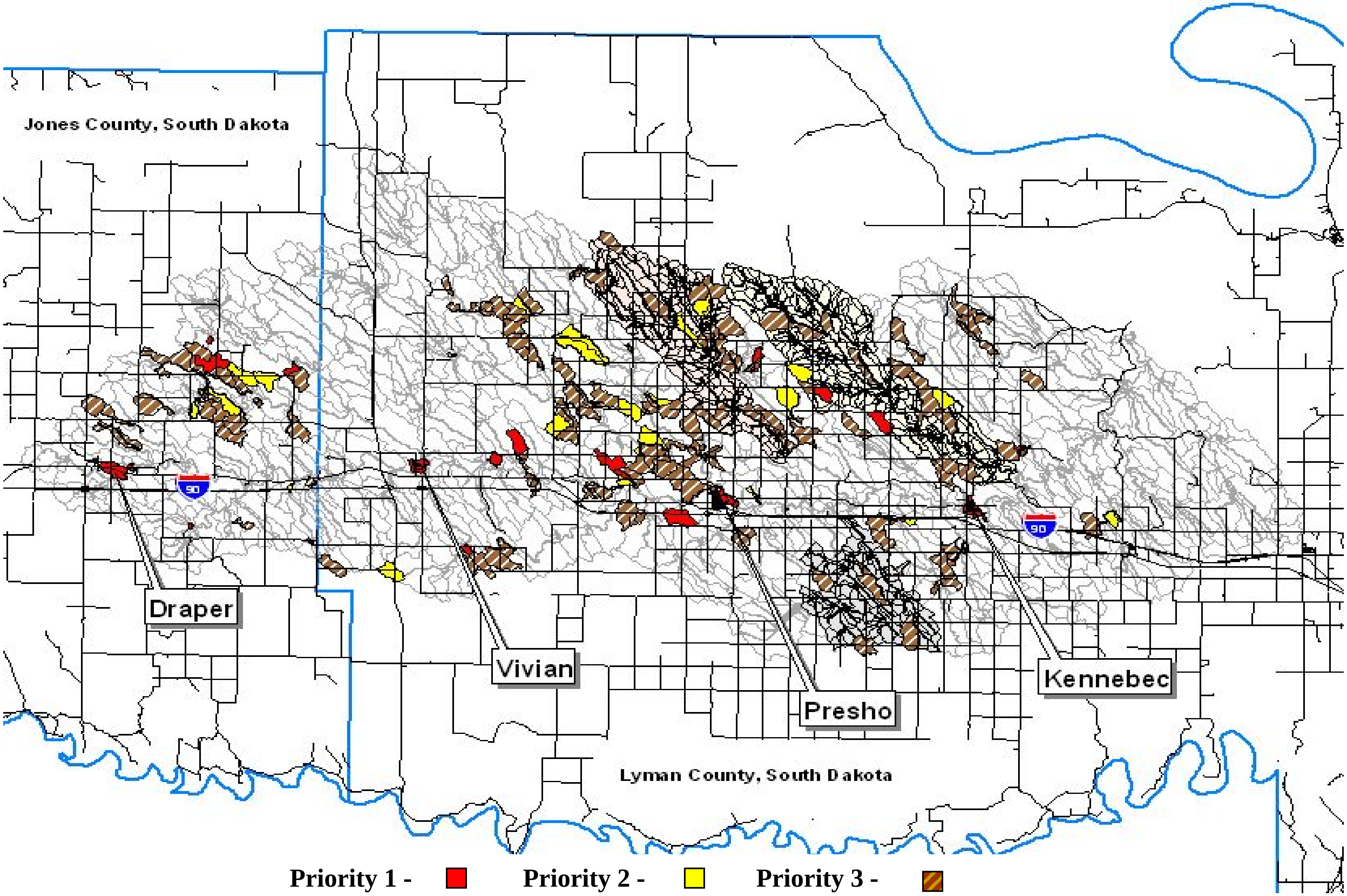

Figure C-2. AnnAGNPS Medicine Creek critical sediment cells by priority ranking based on data from 2000 through 2004.

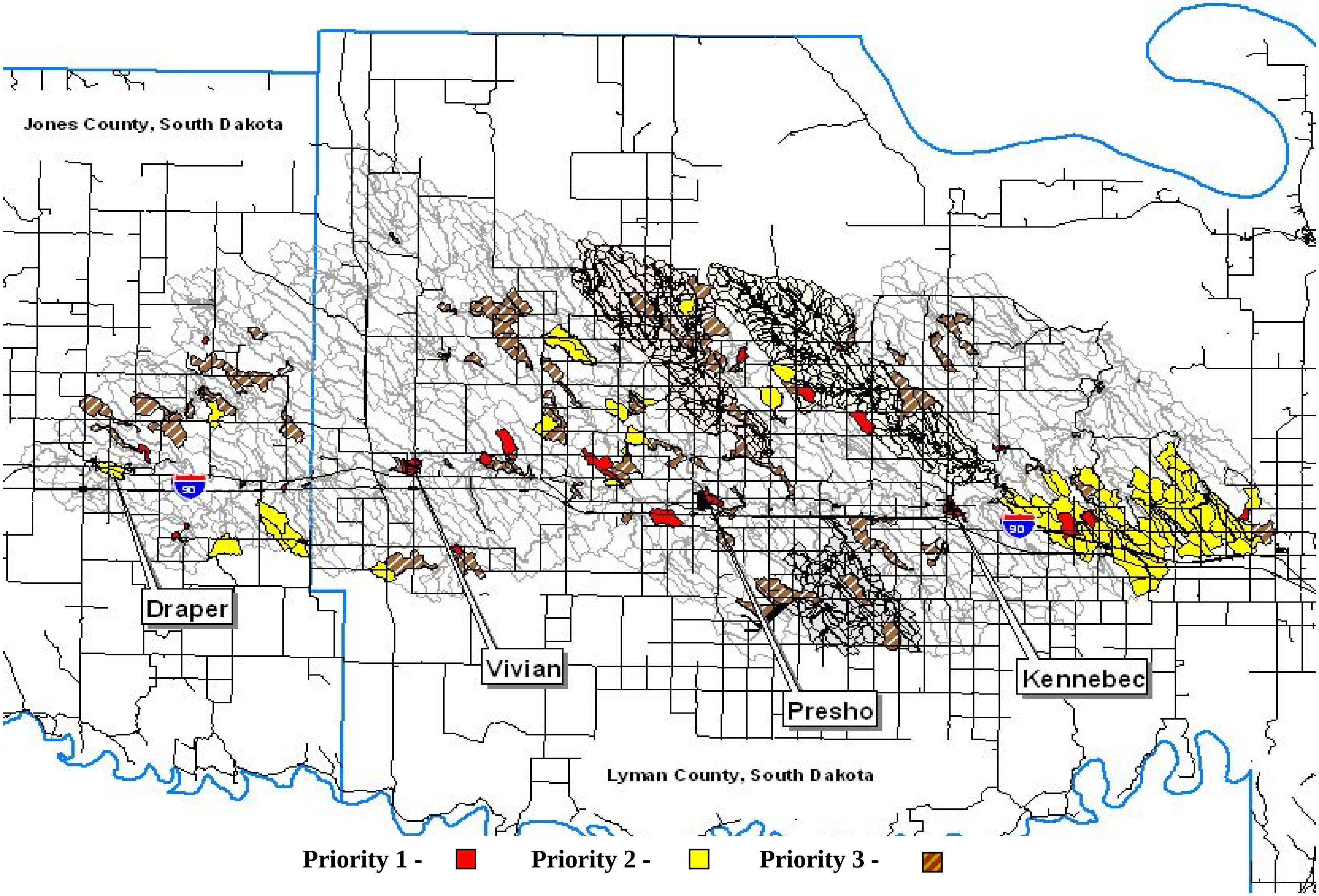

Figure C-3. AnnAGNPS Medicine Creek critical nitrogen cells by priority ranking based on data from 2000 through 2004.

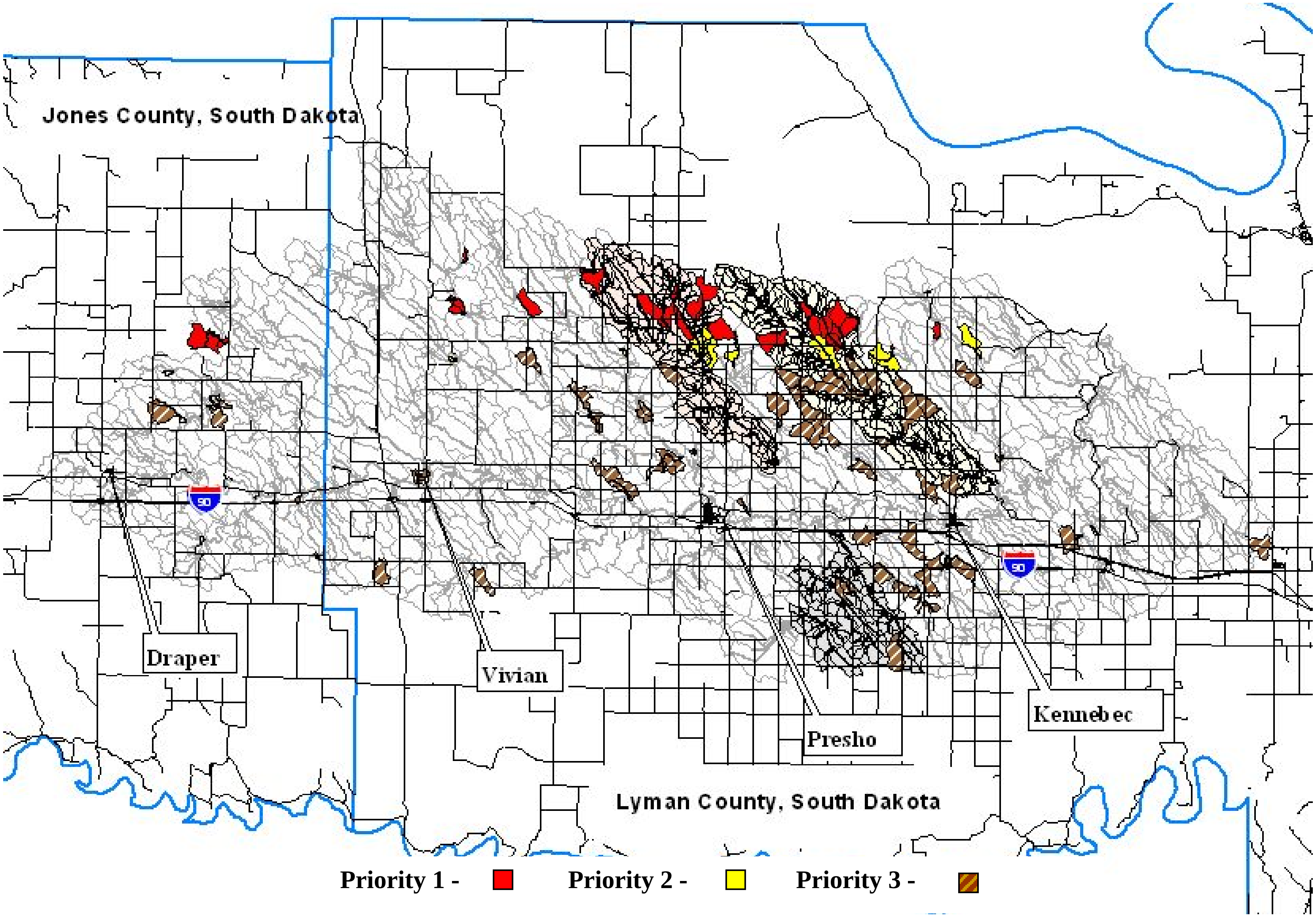

Figure C-4. AnnAGNPS Medicine Creek critical phosphorus cells by priority ranking based on data from 2000 through 2004.

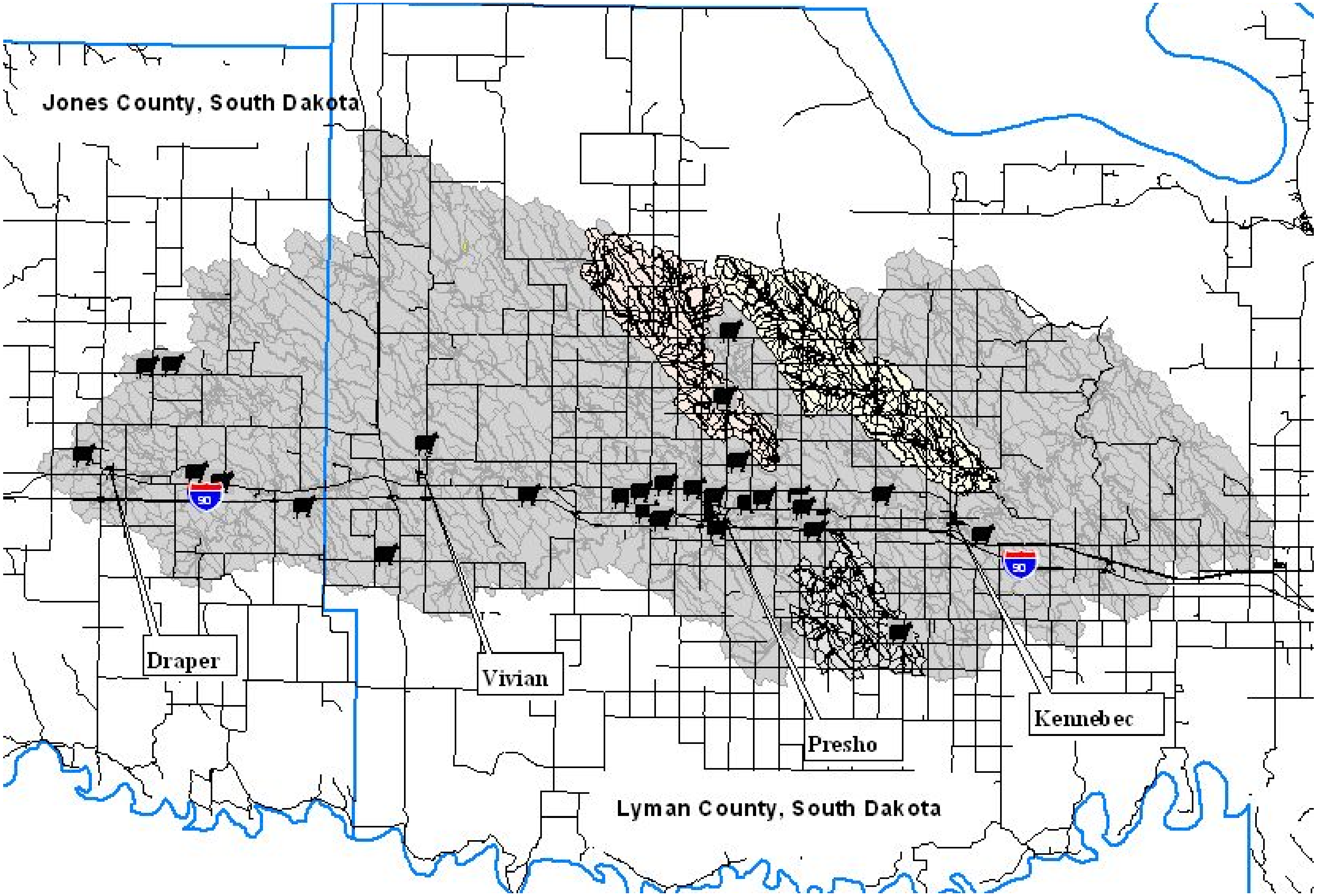

Figure C-5. AnnAGNPS Medicine Creek feedlot locations based on data from 2000 through 2004.

Table C-2. Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
1	2,333	17.79	1	2,333	17.79	1	4,142	28.19
1	3,511	325.58	1	3,511	325.58	1	4,502	305.35
1	3,512	102.52	1	3,512	102.52	1	5,873	150.42
1	5,563	34.47	1	2,522	23.35	1	4,821	79.49
1	2,522	23.35	1	3,193	31.80	1	3,973	417.19
1	3,193	31.80	1	5,563	34.47	1	3,973	502.09
1	2,593	338.71	1	2,023	212.61	1	4,921	95.39
1	843	231.51	1	843	231.51	1	3,972	407.84
1	2,023	212.61	1	5,312	208.16	1	4,892	221.78
1	3,061	379.40	1	1,642	290.89	1	3,962	0.22
1	5,312	208.16	1	172	93.63	1	3,962	90.18
1	2,063	69.39	1	592	154.12	1	3,953	0.22
1	1,642	290.89	1	2,063	69.39	1	4,353	79.67
1	5,261	296.45	1	2,383	24.24	1	4,922	23.96
1	5,023	119.87	1	583	32.47	1	4,913	756.54
1	3,481	310.46	1	2,713	111.20	1	5,422	104.98
1	1,953	126.54	1	2,513	52.26	1	5,832	392.26
1	3,123	104.53	1	5,261	296.45	1	5,471	183.07
1	1,661	420.32	1	3,481	310.46	1	4,853	299.91
1	1,072	29.13	1	5,023	119.87	1	4,852	25.74
2	3,573	349.16	1	1,953	126.54	1	5,473	224.99
2	5,321	307.79	1	633	375.62	1	5,403	325.25
2	3,071	324.25	1	1,661	420.32	1	5,472	387.92
2	2,303	29.58	1	1,072	29.13	1	5,803	297.80
2	4,251	320.47	1	2,303	29.58	1	4,892	297.76
2	2,111	310.02	2	2,593	338.71	1	4,931	1.13
2	2,932	314.24	2	2,111	310.02	1	3,192	480.22
2	1,743	109.42	2	5,321	307.79	1	3,193	0.67
2	4,193	6.45	2	3,573	349.16	1	5,453	262.20
2	3,631	339.15	2	4,251	320.47	1	5,453	250.14
2	5,062	448.12	2	1,743	109.42	1	5,453	303.90
2	4,322	442.34	2	5,062	448.12	1	3,203	301.34
2	592	154.12	2	4,322	442.34	1	5,453	178.46
2	4,313	523.07	2	2,951	296.67	1	5,623	317.13
2	3,583	37.58	2	3,631	339.15	1	5,452	216.74
2	2,973	101.86	2	4,313	523.07	1	3,202	299.27
2	4,352	150.12	2	653	160.12	1	5,351	89.43
2	2,942	20.91	2	651	296.90	2	4,542	19.23
2	4,582	147.89	2	603	312.69	2	4,883	307.09

Table C-2 (continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
2	4,922	73.83	2	732	59.16	2	4,542	7.75
2	4,632	61.16	2	563	986.98	2	4,882	77.53
2	5,521	300.90	2	593	225.51	2	5,773	7.37
2	4,252	19.79	2	631	357.39	2	5,362	77.31
2	1,063	61.16	2	733	89.85	2	3,703	0.22
2	3,081	304.68	2	752	902.25	2	5,613	342.69
2	4,793	279.10	2	163	185.70	2	4,932	0.22
2	4,913	242.41	2	552	368.28	2	5,362	47.48
3	2,953	40.70	2	701	325.36	2	5,012	17.95
3	2,733	177.92	2	731	310.24	2	5,363	0.22
3	4,623	116.53	2	4,922	73.83	2	5,012	207.50
3	5,623	12.90	2	351	363.61	2	4,933	302.64
3	5,902	139.44	2	412	540.19	2	4,933	313.05
3	4,202	302.23	2	501	374.07	2	5,612	20.11
3	5,242	10.01	2	531	505.95	2	5,612	0.22
3	3,633	158.57	2	562	533.52	3	4,202	105.37
3	4,343	289.33	2	602	109.20	3	5,012	233.13
3	5,313	161.01	2	301	307.13	3	3,043	0.22
3	2,082	184.81	2	383	245.75	3	4,741	0.22
3	2,882	30.91	2	423	334.48	3	5,322	0.45
3	3,063	318.47	2	431	500.16	3	5,321	406.88
3	3,553	133.44	2	553	244.19	3	5,781	308.25
3	4,222	140.33	2	153	110.75	3	5,433	27.25
3	913	174.80	2	391	297.79	3	5,323	6.35
3	3,513	214.61	2	551	298.23	3	5,322	161.89
3	1,173	285.33	2	561	396.08	3	5,343	0.22
3	2,883	20.02	2	581	348.49	3	5,501	12.82
3	2,903	154.56	2	671	297.34	3	5,342	60.77
3	4,263	110.97	2	382	214.83	3	5,313	134.00
3	3,582	17.12	2	411	296.45	3	5,303	31.63
3	5,793	251.97	2	421	303.12	3	2,962	435.73
3	2,862	418.10	2	632	58.49	3	2,962	0.22
3	3,581	301.79	2	202	343.15	3	2,952	0.22
3	4,583	85.62	2	203	442.12	3	4,223	269.62
3	5,772	151.23	2	212	531.74	3	4,583	29.76
3	633	375.62	2	213	440.78	3	5,521	0.22
3	902	40.25	2	221	354.27	3	4,263	14.82
3	4,221	310.46	2	413	136.55	3	5,311	58.58
3	1,032	62.72	2	543	136.77	3	3,002	238.89
3	1,261	392.75	2	443	113.87	3	5,062	182.94
3	1,722	87.40	2	201	321.14	3	2,962	8.31

Table C-2 (continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
3	4,882	114.31	2	211	297.79	3	4,212	278.36
3	4,982	253.31	2	223	255.53	3	4,212	368.86
3	583	32.47	2	231	298.68	3	4,213	162.57
3	2,613	5.34	2	183	223.28	3	4,212	242.49
3	2,952	88.51	2	182	170.80	3	5,243	270.28
3	4,172	72.06	2	222	191.26	3	5,513	12.99
3	4,201	318.69	2	3,583	37.58	3	5,071	0.22
3	5,072	34.69	2	171	296.45	3	5,081	213.49
3	903	29.80	2	502	54.04	3	5,262	246.00
3	1,833	23.80	2	582	49.82	3	5,131	0.22
3	2,061	301.79	2	523	40.48	3	4,603	299.75
3	3,121	325.36	2	393	48.70	3	4,602	309.99
3	4,693	365.62	2	4,193	6.45	3	5,112	0.22
3	1,172	31.58	2	2,341	497.05	3	3,553	17.05
3	2,751	353.61	2	2,331	299.12	3	5,563	303.78
3	4,161	306.24	2	2,401	298.45	3	2,023	85.76
3	4,341	297.79	2	4,913	242.41	3	3,562	56.46
3	4,702	43.14	2	2,332	189.03	3	3,552	0.22
3	4,921	312.46	2	4,582	147.89	3	3,563	0.22
3	5,043	9.79	2	2,441	504.17	3	5,112	105.27
3	1,843	85.18	2	392	18.90	3	3,511	111.36
3	4,502	44.92	3	1,063	61.16	3	2,023	57.50
3	5,552	29.36	3	4,352	150.12	3	2,303	215.77
3	5,602	135.44	3	5,521	300.90	3	2,303	309.93
3	1,161	299.12	3	4,252	19.79	3	2,303	0.89
3	1,543	265.09	3	5,313	161.01	3	5,191	0.22
3	2,732	248.64	3	4,793	279.10	3	3,512	270.86
3	3,623	551.76	3	403	1.11	3	3,513	181.50
3	4,163	102.08	3	3,513	214.61	3	5,161	0.22
3	4,542	25.58	3	3,553	133.44	3	2,303	32.57
3	5,513	753.69	3	4,623	116.53	3	4,632	0.22
3	5,792	116.09	3	3,061	379.40	3	1,061	0.22
3	2,253	19.57	3	181	362.28	3	583	0.45
3	2,753	169.24	3	5,623	12.90	3	583	28.86
3	3,542	199.26	3	3,633	158.57	3	2,522	17.77
3	5,232	53.82	3	4,882	114.31	3	1,173	306.30
3	1,033	60.71	3	4,632	61.16	3	633	42.94
3	1,243	469.03	3	2,903	154.56	3	893	110.46
3	2,282	61.16	3	5,902	139.44	3	913	99.75
3	4,231	422.77	3	5,513	753.69	3	2,333	123.96
3	4,852	425.22	3	4,202	302.23	3	181	33.82

Table C-2 (continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
3	3,482	23.57	3	2,732	248.64	3	1,061	168.32
3	3,632	359.61	3	3,582	17.12	3	902	0.67
3	4,931	406.31	3	4,222	140.33	3	913	0.89
3	5,032	61.60	3	4,852	425.22	3	903	365.28
3	5,691	306.24	3	4,343	289.33	3	903	348.51
3	1,793	92.52	3	1,172	31.58	3	1,162	216.80
3	1,802	596.24	3	2,082	184.81	3	1,162	364.29
3	1,842	53.82	3	5,242	10.01	3	1,142	0.22
3	2,962	284.00	3	1,173	285.33	3	893	0.22
3	3,201	297.56	3	913	174.80	3	1,162	470.33
3	3,982	128.32	3	4,931	406.31	3	2,261	80.89
3	4,942	32.02	3	4,263	110.97	3	1,262	286.00
3	4,943	40.25	3	4,653	28.69	3	1,263	0.14
3	4,983	125.87	3	1,243	469.03	3	2,061	174.70
3	5,403	196.82	3	5,793	251.97	3	1,031	34.26
3	5,621	300.68	3	2,932	314.24	3	1,093	242.58
3	1,832	33.58	3	3,702	23.57	3	1,142	62.26
3	2,923	358.94	3	3,922	9.56	3	1,103	326.65
3	3,561	337.59	3	3,692	10.23	3	1,103	377.62
3	3,572	389.63	3	5,492	149.67	3	1,272	288.43
3	4,482	51.82	3	1,161	299.12	3	1,112	52.09
3	5,432	330.26	3	2,992	672.74	3	1,132	197.89
3	1,102	159.23	3	1,261	392.75	3	1,113	31.96
3	3,443	42.92	3	5,442	34.25	3	1,243	19.81
3	3,483	64.27	3	4,221	310.46	3	1,243	91.74
3	4,883	94.74	3	1,833	23.80	3	1,243	34.10
3	4,911	297.12	3	4,921	312.46			
3	5,372	855.33	3	3,071	324.25			
3	5,901	309.57	3	3,443	42.92			
3	1,262	97.41	3	4,982	253.31			
3	1,653	868.45	3	5,812	371.40			
3	1,723	16.68	3	4,643	552.87			
3	2,432	105.19	3	4,883	94.74			
3	3,642	64.27	3	4,663	25.35			
3	4,932	178.80	3	1,313	859.55			
3	4,941	297.34	3	2,993	41.81			
3	4,953	403.65	3	1,383	393.86			
3	2,321	298.45	3	5,823	9.56			
3	4,601	429.22	3	1,373	102.75			
3	5,042	42.25	3	3,123	104.53			
3	5,562	45.37	3	5,043	9.79			

Table C-2 (continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
3	5,903	34.69	3	1,333	47.37			
3	1,301	334.48	3	1,363	60.71			
3	1,721	499.50	3	1,372	52.71			
3	1,873	52.71	3	1,393	38.47			
3	2,921	309.57	3	1,323	26.46			
3	3,543	84.29	3	903	29.80			
3	4,233	27.58	3	2,952	88.51			
3	4,731	303.12	3	1,362	17.57			
3	5,511	299.79	3	5,822	4.45			
3	1,902	76.06	3	2,973	101.86			
3	4,232	9.12	3	4,502	44.92			
3	4,581	322.47	3	4,583	85.62			
3	4,622	76.50	3	2,942	20.91			
3	4,861	299.12	3	5,072	34.69			
3	5,161	308.68	3	4,542	25.58			
3	5,221	308.46	3	4,172	72.06			
3	5,561	335.15	3	1,843	85.18			
3	1,031	346.93	3	3,273	142.33			
3	1,822	208.83	3	3,581	301.79			
3	1,893	49.15	3	2,113	687.20			
3	3,002	517.73	3	2,751	353.61			
3	3,033	726.78	3	2,953	40.70			
3	3,533	62.94	3	1,032	62.72			
3	3,563	104.53	3	902	40.25			
3	4,483	56.71	3	1,143	255.53			
3	4,722	225.95	3	4,693	365.62			
3	4,933	221.06	3	5,602	135.44			
3	5,191	298.68	3	2,061	301.79			
3	1,132	59.38	3	3,632	359.61			
3	1,153	86.07	3	4,201	318.69			
3	1,431	308.46	3	5,032	61.60			
3	1,542	144.33	3	5,233	28.24			
3	2,951	296.67	3	512	247.52			
3	3,042	93.63	3	722	60.49			
3	3,703	23.80	3	663	43.59			
3	3,953	90.29	3	3,482	23.57			
3	4,152	76.73	3	4,341	297.79			
3	4,353	296.67	3	5,552	29.36			
3	4,592	41.81	3	62	3.34			
3	4,683	146.78	3	763	23.35			
3	4,821	304.68	3	1,522	107.86			
3	5,141	302.90	3	1,722	87.40			
3	5,522	404.09	3	5,772	151.23			

Table C-2 (continued). Critical cells by priority ranking for sediment, nitrogen and phosphorus in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on 2000 through 2004 data.

Sediment			Total Nitrogen			Total Phosphorus		
Priority	Cell	Acres	Priority	Cell	Acres	Priority	Cell	Acres
			3	682	48.48			
			3	4,283	22.46			
			3	4,933	221.06			
			3	692	13.57			
			3	1,203	19.79			
			3	473	28.47			
			3	1,482	20.91			
			3	3,703	23.80			
			3	3,081	304.68			
			3	862	5.12			
			3	2,022	48.70			
			3	2,123	124.10			
			3	4,161	306.24			
			3	4,163	102.08			
			3	263	17.35			
			3	2,862	418.10			
			3	4,562	3.11			
			3	4,563	2.67			
			3	272	9.56			
			3	273	13.34			
			3	3,663	119.87			
			3	1,862	71.17			
			3	1,913	171.47			
			3	3,002	517.73			
			3	3,643	82.29			
			3	4,003	35.81			
			3	1,903	35.14			
			3	1,933	29.58			
			3	1,993	33.58			
			3	3,542	199.26			
			3	3,942	12.45			
			3	3,953	90.29			
			3	4,983	125.87			
			3	3,442	52.93			
			3	1,543	265.09			
			3	3,483	64.27			
			3	2,253	19.57			
			3	2,753	169.24			
			3	4,353	296.67			

AnnAGNPS Load Reduction Estimates

Medicine Creek watershed is identified as producing considerable total dissolved solids loading and high conductivity readings resulting violations in assigned beneficial use water quality standards (SD DENR, 2002 and SD DENR, 2004). Three lakes Byre Lake, Brakke Dam and Fate Dam sub-watersheds are within the Medicine Creek watershed and are depicted in Figure C-2 through Figure C-5. These lakes are listed separately for increased Trophic State Index (TSI) values within the Medicine Creek watershed (SD DENR, 1998, SD DENR, 2002 and SD DENR, 2004). Overall watershed wide BMP reductions for sediment will in-turn reduce nutrient loading in selected sub-watersheds (Byre Lake, Brakke Dam and Fate Dam) where nutrients (phosphorus) are a problem.

Existing conditions for the years 2000 through 2004, including row crop, pasture, fertilizer application rates, buffers, feedlots and tillage practices were modeled using AnnAGNPS in 2004. Initial conditions were modeled and loads were estimated at the outlet cell of the watershed (Table C-3). To model the best possible condition the watershed could attain, land use in the watershed was converted to all grass. Data indicate under ideal conditions, annual sediment would be dramatically reduced while nutrients would be much less reduced. AnnAGNPS estimated reductions by converting current field conditions to an all grass condition would result in an estimated sediment reduction of 80.0 percent. This reduction would significantly reduce sediment loading to Medicine Creek; however, this scenario (converting the entire watershed to grass) is not realistic based on logistical, technical and/or financial constraints.

Table C-3. Modeled initial condition and best possible condition for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Entire Watershed All Grass	0.001	0.260	3.626
Percent Reduction	**80.0**	**4.4**	**1.3**

[1] = Load reduction calculated at the outlet of the watershed.

AnnAGNPS was used to predict/estimate nutrient load reductions with reduced fertilizer application rates (based on average 2000 through 2004 field application rates). Fertilizer reduction modeling was done by reduced phosphorus fertilizer application rates from moderate to low in all priority one sediment cells in the Medicine Creek watershed. Priority one sediment critical cells are listed in Table C-2. Application rates varied in the type and amount of fertilizer applied throughout the watershed. Nitrogen and phosphorus in combination, nitrogen only or phosphorus only may be applied depending upon field, crop and/or tillage practice. Phosphorus applications rates also varied from moderate to low in pounds/acre.

Table C-4. Modeled initial condition and fertilizer reduction for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Fertilizer Reduction[2]	0.005	0.270	3.620
Percent Reduction	**0.0**	**0.7**	**1.5**

[1] = Load reduction calculated at the outlet of the watershed.
[2] = Reduced phosphorus fertilizer application rates from moderate to low in all priority-one sediment cells

Reductions were modeled by reducing phosphorus and nitrogen application rates in fields where phosphorus application rates were at moderate levels in priority-one sediment cells. By reducing phosphorus application rates in selected cells one level (moderate to low); overall estimated phosphorus loading was reduced by 1.5 percent (Table C-4).

AnnAGNPS was again used to predict/estimate phosphorus load reduction based on grazing management. Field data on pastures in the Medicine Creek watershed indicated pasture locations but did not delineate specific grass conditions by pasture. The district manager for the American Creek Conservation District (ACCD) indicated that the majority of the pasture in this watershed was in reasonably fair condition. Based on this, the rating of the existing condition used in the model for all pastures was "fair". Phosphorus reductions were modeled by switching all existing pasture from fair (grass two to four inches in height) to "good" (grass four to six inches in height).

Table C-5. Modeled initial condition and grazing management improvements for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Grazing Management[2]	0.004	0.244	3.354
Percent Reduction	**20.0**	**10.3**	**8.7**

[1] = Load reduction calculated at the outlet of the watershed.
[2] = Modeled all pastures from fair condition (grass two to four inches high) to good condition (grass four to six inches high).

Sediment, nitrogen and phosphorus reductions based on grazing management improvements on all current pastures in the Medicine Creek watershed indicated overall estimated sediment, nitrogen and phosphorus reductions were relatively high (Table C-5). Grazing management reductions in sediment, nitrogen and phosphorus were the largest in comparison to other modeled

BMPs in the watershed. With a large percentage of the watershed composed of grass and pasture, it was expected that improvements in grazing management practices would result in better overall reductions in sediment and nutrients.

The district manager for the ACCD indicated that stakeholder participation during BMP implementation can be expected to be approximately 20 percent. All tillage practices were modified (converted to no tillage) in all cropped priority one critical sediment cells (11 of 20 critical cells or approximately 2,330 acres out of 3,673 priority-one sediment acres (63.4 percent)) to estimate reductions. AnnAGNPS predicted a 20.0 percent sediment reduction by converting cropped sediment critical cell tillage to no tillage (Table C-6).

Table C-6. Modeled initial condition and conservation tillage for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Conservation Tillage Reduction[2]	0.004	0.270	3.672
Percent Reduction	**20.0**	**0.7**	**0.05**

[1] = Load reduction calculated at the outlet of the watershed.
[2] = Modeled cropped priority-one sediment critical cells that are currently minimum tillage to no tillage.

AnnAGNPS was also used to predict/estimate sediment and nutrient load reduction based on buffer management. Sediment priority-one critical cells for Medicine Creek were converted from current crops to all grass and modeled using AnnAGNPS. Parameter specific reduction results were again reduced by 50 percent for a more conservative sediment, nitrogen and phosphorus reductions (better simulates typical buffer reduction). AnnAGNPS predicted reductions were 10.0 percent sediment, 0.7 percent nitrogen and no reduction in phosphorus by applying buffer strips to sediment priority-one critical cells (Table C-7).

Table C-7. Modeled initial condition and buffer strips for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Buffer Strips[2]	0.0045	0.270	3.674
Percent Reduction	**10.0**	**0.7**	**0.0**

[1] = Load reduction calculated at the outlet of the watershed.
[2] = Modeled by converting all priority-one sediment critical cells to grass and further reducing the output 50 percent to better represent buffers.

Thirty-eight animal feeding areas were identified in the Medicine Creek drainage. Four cells (1,533, 1,672, 1,673 and 3,052) had multiple feeding areas in each cell. Figure C- 5 depicts locations of animal feeding areas in the watershed. One CAFO (Confined Animal Feeding Operation) is located in the Medicine Creek watershed (cell 1,672 and 1,673). As of September 2002, this feedlot has an approved agricultural waste management plan; however, containment construction had not been completed and therefore the facility is not currently permitted.

Table C-8. Modeled initial condition and feedlot reductions for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004[1].

Best Management Practice	Sediment (tons/acre/year)	Nitrogen (lbs/acre/year)	Phosphorus (lbs/acre/year)
Initial Condition	0.005	0.272	3.674
Feedlots[2]	0.005	0.272	3.674
Percent Reduction	**0.0**	**0.0**	**0.0**

[1] = Load reduction calculated at the outlet of the watershed.
[2] = Modeled by removing nine feedlots in the Medicine Creek watershed rating over sixty.

Feedlot reduction modeling was performed to estimate sediment and nutrient reductions by removing nine feeding areas that rated sixty and over in the Medicine Creek watershed. Feedlot rating consisted of entering feedlot parameters into a SD DENR feedlot program which calculates COD, nitrogen and phosphorus values and rating numbers for AnnAGNPS data entry. Estimated sediment and nutrient load reductions for feedlots were modeled by removing all feedlots rating at or above 60. Nine feedlots were removed and modeled by AnnAGNPS with no average overall load reductions in sediment, nitrogen or phosphorus at the outlet of Medicine Creek (Table C-8). Table C-8 indicates that estimated AnnAGNPS average annual sediment in tons/acre/year and nutrients lbs/acre/year load reductions may average out or mask cell specific load reductions in the Medicine Creek watershed.

To determine feedlot reductions for priority ranking of feedlots rating at or above 60, specific feedlot cells were analyzed separately based on a simulated maximum 24 hour rain event. One day sediment and nutrient loads from each feedlot cell in the initial AnnAGNPS run were compared to the same cells without feedlots to determine event based cell specific reductions for priority ranking. Feedlot specific load reductions and priority ranking are provided in Table C-9. Cell specific removal of feedlots had no affect on sediment load reduction so feedlots could not be priority ranked; however, nitrogen and phosphorus load reductions were detected and priority ranked. Cell 4,663 had the highest load reduction for both nitrogen and phosphorus and ranked as priority one (Table C-9). Many nitrogen and phosphorus priority rankings were similar for each feedlot cell except for priority five through eight rankings which switching one priority position each.

Table C-9. Modeled feedlot priority ranking for sediment, nitrogen and phosphorus based on one cell specific 24 hour event for feedlots rating over sixty in the Medicine Creek watershed, Lyman and Jones Counties, South Dakota using AnnAGNPS.

	Sediment		Nitrogen		Phosphorus	
Feedlot Cell Number	**tons/acre reduction**	**Priority rank**	**lbs/acre reduction**	**Priority rank**	**lbs/acre reduction**	**Priority rank**
822	0.0	-	0.004	8	0.020	7
1,473	0.0	-	0.188	6	0.137	5
1,653	0.0	-	1.805	2	1.092	2
1,672	0.0	-	0.021	7	0.007	8
1,673	0.0	-	0.860	3	0.329	3
1,533	0.0	-	0.647	4	0.246	4
2,563	0.0	-	0.239	5	0.128	6
4,663	0.0	-	6.699	1	2.548	1
4,752	0.0	-	0.000	9	0.001	9

CONCLUSION

Modeled BMP reductions were: fertilizer, grazing management, conservation tillage, buffer strips and feedlots. The combination of increased implementation of fertilizer, grazing management, conservation tillage, buffer strips and feedlots will result in estimated annual load reductions in sediment nitrogen and phosphorus (Table C-10). Installing these practices on priority critical cells the Medicine Creek will reduce the amount of sediment, nitrogen and phosphorus entering Medicine Creek on a per acre basis annually. Grazing management and conservation tillage had the greatest impact on overall sediment reductions while fertilizer, grazing management reductions had the greatest impact on nitrogen and phosphorus loading (Table C-10).

Table C-10. AnnAGNPS modeled overall BMP reduction percentages for the Medicine Creek watershed, Lyman and Jones Counties, South Dakota based on AnnAGNPS data from 2000 through 2004.

	Sediment		Nitrogen		Phosphorus	
Best Management Practice	**Reduction (tons/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**	**Reduction (lbs/acre/yr)**	**Percent Reduction**
Fertilizer Reduction	0.000	0.0	0.002	0.74	0.054	1.47
Grazing Management Reduction	0.001	20.0	0.028	10.29	0.020	0.54
Conservation Tillage Reduction	0.001	20.0	0.002	0.74	0.002	0.05
Buffer Strips Reduction	0.0005	10.0	0.002	0.74	0.000	0.0
Feedlot Reductions	0.000	0.0	0.000	0.0	0.000	0.0
Estimated Overall Reduction	**0.0025**	**-**	**0.034**	**-**	**0.074**	**-**

It is recommended that efforts to reduce sediment and nutrients be targeted to the installation of appropriate BMPs that include but are not limited to grazing management, conservation tillage on cropland, fertilizer reduction, buffer/filter strips and feedlot agricultural waste systems. BMPs should also be implemented/installed in sediment, nitrogen and phosphorus priority-one and two critical cells throughout the Medicine Creek watershed. This will reduce sediment and nutrient loading throughout the watershed and will reduce violations in total dissolved solids, total suspended solids, conductivity and fecal coliform bacteria.

The implementation of appropriate BMPs and targeting field verified critical cells in priority sub-watersheds, should produce the most cost-effective treatment plan for reducing sediment and nutrient yields from the Medicine Creek watershed.

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ATTACHMENT A

Feedlot Rating Datasheets

AnnAGNPS Data

Lot ID Cell 1533A

Lot Area in Acres	**12.5**	**Upslope Area:**	**0**	**Duration:**	**180**	**Rating #:**	**0**
Feedlot Initial N	17	Delta N	0.036	Feedlot Max N		Pack N	100
Feedlot Initial P	11	Delta P	0.014	Feedlot Max P		Pack P	100
Feedlot Initial C	336	Delta C	0.840	Feedlot Max C		Pack C	100

Lot ID Cell 1533B

Lot Area in Acres	**8.2**	**Upslope Area:**	**2.1**	**Duration:**	**365**	**Rating #:**	**43**
Feedlot Initial N	2	Delta N	0.000	Feedlot Max N	14	Pack N	100
Feedlot Initial P	2	Delta P	0.000	Feedlot Max P	4	Pack P	100
Feedlot Initial C	38	Delta C	0.000	Feedlot Max C	274	Pack C	100

Lot ID Cell 1533C

Lot Area in Acres	**4.5**	**Upslope Area:**	**25**	**Duration:**	**250**	**Rating #:**	**73**
Feedlot Initial N	8	Delta N	0.000	Feedlot Max N	10	Pack N	100
Feedlot Initial P	6	Delta P	0.000	Feedlot Max P	3	Pack P	100
Feedlot Initial C	138	Delta C	0.000	Feedlot Max C	190	Pack C	100

Lot ID Cell 1183

Lot Area in Acres	**6.8**	**Upslope Area:**	**0**	**Duration:**	**365**	**Rating #:**	**30**
Feedlot Initial N	2	Delta N	0.005	Feedlot Max N	12	Pack N	100
Feedlot Initial P	1	Delta P	0.002	Feedlot Max P	4	Pack P	100
Feedlot Initial C	44	Delta C	0.124	Feedlot Max C	199	Pack C	100

Lot ID Cell 1222

Lot Area in Acres	**3.5**	**Upslope Area:**	**0.3**	**Duration:**	**180**	**Rating #:**	**45**
Feedlot Initial N	15	Delta N	0.000	Feedlot Max N	106	Pack N	100
Feedlot Initial P	12	Delta P	0.000	Feedlot Max P	32	Pack P	100
Feedlot Initial C	266	Delta C	0.000	Feedlot Max C	2085	Pack C	100

AnnAGNPS Data

Lot ID	Cell 1321						
Lot Area in Acres	**1**	**Upslope Area:**	**1**	**Duration:**	**180**	**Rating #:**	**52**
Feedlot Initial N	0	Delta N	0.000	Feedlot Max N	133	Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P	40	Pack P	100
Feedlot Initial C	0	Delta C	0.000	Feedlot Max C	2132	Pack C	100

Lot ID	Cell 1413						
Lot Area in Acres	**0.9**	**Upslope Area:**	**0**	**Duration:**	**180**	**Rating #:**	**0**
Feedlot Initial N	12	Delta N	0.000	Feedlot Max N		Pack N	100
Feedlot Initial P	9	Delta P	0.000	Feedlot Max P		Pack P	100
Feedlot Initial C	207	Delta C	0.000	Feedlot Max C		Pack C	100

Lot ID	Cell 1443						
Lot Area in Acres	**1**	**Upslope Area:**	**2.6**	**Duration:**	**180**	**Rating #:**	**48**
Feedlot Initial N	27	Delta N	0.000	Feedlot Max N	70	Pack N	100
Feedlot Initial P	20	Delta P	0.000	Feedlot Max P	21	Pack P	100
Feedlot Initial C	465	Delta C	0.000	Feedlot Max C	1386	Pack C	100

Lot ID	Cell 1533						
Lot Area in Acres	**4**	**Upslope Area:**	**5.9**	**Duration:**	**365**	**Rating #:**	**78**
Feedlot Initial N	51	Delta N	0.255	Feedlot Max N	246	Pack N	100
Feedlot Initial P	21	Delta P	0.098	Feedlot Max P	75	Pack P	100
Feedlot Initial C	1188	Delta C	5.950	Feedlot Max C	3916	Pack C	100

Lot ID	Cell 1643						
Lot Area in Acres	**1.3**	**Upslope Area:**	**0.4**	**Duration:**	**180**	**Rating #:**	**38**
Feedlot Initial N	33	Delta N	0.138	Feedlot Max N	189	Pack N	100
Feedlot Initial P	17	Delta P	0.053	Feedlot Max P	57	Pack P	100
Feedlot Initial C	720	Delta C	3.231	Feedlot Max C	3175	Pack C	100

Lot ID	Cell 1653						
Lot Area in Acres	**1**	**Upslope Area:**	**0.3**	**Duration:**	**180**	**Rating #:**	**20**
Feedlot Initial N	7	Delta N	0.000	Feedlot Max N	43	Pack N	100
Feedlot Initial P	5	Delta P	0.000	Feedlot Max P	13	Pack P	100
Feedlot Initial C	124	Delta C	0.000	Feedlot Max C	843	Pack C	100

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Lot ID Cell 1672

Lot Area in Acres	**5.7**	**Upslope Area:**	**3.7**	**Duration:**	**365**	**Rating #:**	**61**
Feedlot Initial N	9	Delta N	0.000	Feedlot Max N	42	Pack N	100
Feedlot Initial P	7	Delta P	0.000	Feedlot Max P	13	Pack P	100
Feedlot Initial C	152	Delta C	0.000	Feedlot Max C	825	Pack C	100

Lot ID Cell 1672A

Lot Area in Acres	**5**	**Upslope Area:**	**1.7**	**Duration:**	**365**	**Rating #:**	**44**
Feedlot Initial N	5	Delta N	0.030	Feedlot Max N	27	Pack N	100
Feedlot Initial P	2	Delta P	0.012	Feedlot Max P	8	Pack P	100
Feedlot Initial C	125	Delta C	0.700	Feedlot Max C	428	Pack C	100

Lot ID Cell 1673

Lot Area in Acres	**13.8**	**Upslope Area:**	**2.2**	**Duration:**	**365**	**Rating #:**	**68**
Feedlot Initial N	11	Delta N	0.030	Feedlot Max N	61	Pack N	100
Feedlot Initial P	4	Delta P	0.012	Feedlot Max P	18	Pack P	100
Feedlot Initial C	250	Delta C	0.700	Feedlot Max C	979	Pack C	100

Lot ID Cell 1673A

Lot Area in Acres	**2.7**	**Upslope Area:**	**0.4**	**Duration:**	**365**	**Rating #:**	**33**
Feedlot Initial N	6	Delta N	0.031	Feedlot Max N	33	Pack N	100
Feedlot Initial P	2	Delta P	0.012	Feedlot Max P	10	Pack P	100
Feedlot Initial C	130	Delta C	0.726	Feedlot Max C	512	Pack C	100

Lot ID Cell 1673B

Lot Area in Acres	**12.9**	**Upslope Area:**	**0**	**Duration:**	**365**	**Rating #:**	**67**
Feedlot Initial N	9	Delta N	0.000	Feedlot Max N	68	Pack N	100
Feedlot Initial P	7	Delta P	0.000	Feedlot Max P	21	Pack P	100
Feedlot Initial C	154	Delta C	0.000	Feedlot Max C	1340	Pack C	100

Lot ID Cell 1742

Lot Area in Acres	**3.8**	**Upslope Area:**	**8.6**	**Duration:**	**180**	**Rating #:**	**44**
Feedlot Initial N	5	Delta N	0.009	Feedlot Max N	11	Pack N	100
Feedlot Initial P	3	Delta P	0.004	Feedlot Max P	3	Pack P	100
Feedlot Initial C	88	Delta C	0.221	Feedlot Max C	198	Pack C	100

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Lot ID **Cell 1902**

Lot Area in Acres	**0.9**	**Upslope Area:**	**1.9**	**Duration:**	**180**	**Rating #:**	**56**
Feedlot Initial N	0	Delta N	0.000	Feedlot Max N	100	Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P	30	Pack P	100
Feedlot Initial C	0	Delta C	0.000	Feedlot Max C	1614	Pack C	100

Lot ID **Cell 2013**

Lot Area in Acres	**3.2**	**Upslope Area:**	**7**	**Duration:**	**180**	**Rating #:**	**45**
Feedlot Initial N	6	Delta N	0.000	Feedlot Max N	15	Pack N	100
Feedlot Initial P	4	Delta P	0.000	Feedlot Max P	5	Pack P	100
Feedlot Initial C	97	Delta C	0.000	Feedlot Max C	302	Pack C	100

Lot ID **Cell 2161**

Lot Area in Acres	**2.1**	**Upslope Area:**	**2.4**	**Duration:**	**180**	**Rating #:**	**6**
Feedlot Initial N	1	Delta N	0.000	Feedlot Max N	1	Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P	0	Pack P	100
Feedlot Initial C	24	Delta C	0.000	Feedlot Max C	23	Pack C	100

Lot ID **Cell 2302**

Lot Area in Acres	**2.4**	**Upslope Area:**	**1.3**	**Duration:**	**180**	**Rating #:**	**42**
Feedlot Initial N	15	Delta N	0.000	Feedlot Max N	83	Pack N	100
Feedlot Initial P	11	Delta P	0.000	Feedlot Max P	25	Pack P	100
Feedlot Initial C	258	Delta C	0.000	Feedlot Max C	1643	Pack C	100

Lot ID **Cell 2563**

Lot Area in Acres	**2.3**	**Upslope Area:**	**1.4**	**Duration:**	**230**	**Rating #:**	**62**
Feedlot Initial N	9	Delta N	0.052	Feedlot Max N	217	Pack N	100
Feedlot Initial P	4	Delta P	0.020	Feedlot Max P	66	Pack P	100
Feedlot Initial C	217	Delta C	1.217	Feedlot Max C	3483	Pack C	100

Lot ID **Cell 2573**

Lot Area in Acres	**0.8**	**Upslope Area:**	**1.4**	**Duration:**	**180**	**Rating #:**	**52**
Feedlot Initial N	0	Delta N	0.000	Feedlot Max N	114	Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P	35	Pack P	100
Feedlot Initial C	0	Delta C	0.000	Feedlot Max C	1836	Pack C	100

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Lot ID Cell 2673

Lot Area in Acres	**10**	**Upslope Area:**	**1.6**	**Duration:**	**180**	**Rating #:**	**40**
Feedlot Initial N	4	Delta N	0.024	Feedlot Max N	25	Pack N	100
Feedlot Initial P	2	Delta P	0.009	Feedlot Max P	8	Pack P	100
Feedlot Initial C	100	Delta C	0.560	Feedlot Max C	396	Pack C	100

Lot ID Cell 2673A

Lot Area in Acres	**3**	**Upslope Area:**	**0.5**	**Duration:**	**180**	**Rating #:**	**52**
Feedlot Initial N	36	Delta N	0.080	Feedlot Max N	208	Pack N	100
Feedlot Initial P	21	Delta P	0.031	Feedlot Max P	63	Pack P	100
Feedlot Initial C	727	Delta C	1.867	Feedlot Max C	3723	Pack C	100

Lot ID Cell 3052

Lot Area in Acres	**2.7**	**Upslope Area:**	**0.4**	**Duration:**	**365**	**Rating #:**	**51**
Feedlot Initial N	37	Delta N	0.076	Feedlot Max N	235	Pack N	100
Feedlot Initial P	23	Delta P	0.029	Feedlot Max P	71	Pack P	100
Feedlot Initial C	724	Delta C	1.763	Feedlot Max C	4311	Pack C	100

Lot ID Cell 3052A

Lot Area in Acres	**3**	**Upslope Area:**	**0.4**	**Duration:**	**180**	**Rating #:**	**53**
Feedlot Initial N	36	Delta N	0.076	Feedlot Max N	239	Pack N	100
Feedlot Initial P	23	Delta P	0.029	Feedlot Max P	73	Pack P	100
Feedlot Initial C	709	Delta C	1.773	Feedlot Max C	4383	Pack C	100

Lot ID Cell 3053

Lot Area in Acres	**2.2**	**Upslope Area:**	**1.6**	**Duration:**	**365**	**Rating #:**	**59**
Feedlot Initial N	36	Delta N	0.076	Feedlot Max N	166	Pack N	100
Feedlot Initial P	23	Delta P	0.029	Feedlot Max P	50	Pack P	100
Feedlot Initial C	713	Delta C	1.782	Feedlot Max C	3047	Pack C	100

Lot ID Cell 3522

Lot Area in Acres	**0.6**	**Upslope Area:**	**1**	**Duration:**	**180**	**Rating #:**	**2**
Feedlot Initial N	4	Delta N	0.000	Feedlot Max N	6	Pack N	100
Feedlot Initial P	2	Delta P	0.000	Feedlot Max P	2	Pack P	100
Feedlot Initial C	117	Delta C	0.000	Feedlot Max C	90	Pack C	100

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Lot ID **Cell 3522A**

Lot Area in Acres	**2.5**	**Upslope Area:**	**1.1**	**Duration:**	**365**	**Rating #:**	**28**
Feedlot Initial N	4	Delta N	0.002	Feedlot Max N	13	Pack N	100
Feedlot Initial P	2	Delta P	0.001	Feedlot Max P	4	Pack P	100
Feedlot Initial C	93	Delta C	0.056	Feedlot Max C	517	Pack C	100

Lot ID **Cell 3522B**

Lot Area in Acres	**8.7**	**Upslope Area:**	**3.9**	**Duration:**	**180**	**Rating #:**	**63**
Feedlot Initial N	16	Delta N	0.034	Feedlot Max N	85	Pack N	100
Feedlot Initial P	10	Delta P	0.013	Feedlot Max P	26	Pack P	100
Feedlot Initial C	322	Delta C	0.805	Feedlot Max C	1559	Pack C	100

Lot ID **Cell 4633**

Lot Area in Acres	**1**	**Upslope Area:**	**0**	**Duration:**	**180**	**Rating #:**	**0**
Feedlot Initial N	0	Delta N	0.000	Feedlot Max N		Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P		Pack P	100
Feedlot Initial C	0	Delta C	0.000	Feedlot Max C		Pack C	100

Lot ID **Cell 4663**

Lot Area in Acres	**2.1**	**Upslope Area:**	**2.2**	**Duration:**	**180**	**Rating #:**	**64**
Feedlot Initial N	5	Delta N	0.029	Feedlot Max N	166	Pack N	100
Feedlot Initial P	2	Delta P	0.011	Feedlot Max P	51	Pack P	100
Feedlot Initial C	119	Delta C	0.667	Feedlot Max C	2668	Pack C	100

Lot ID **Cell 4672**

Lot Area in Acres	**2**	**Upslope Area:**	**0.4**	**Duration:**	**180**	**Rating #:**	**24**
Feedlot Initial N	8	Delta N	0.045	Feedlot Max N	47	Pack N	100
Feedlot Initial P	3	Delta P	0.017	Feedlot Max P	14	Pack P	100
Feedlot Initial C	188	Delta C	1.050	Feedlot Max C	746	Pack C	100

Lot ID **Cell 4752**

Lot Area in Acres	**4.4**	**Upslope Area:**	**2**	**Duration:**	**180**	**Rating #:**	**34**
Feedlot Initial N	4	Delta N	0.000	Feedlot Max N	23	Pack N	100
Feedlot Initial P	3	Delta P	0.000	Feedlot Max P	7	Pack P	100
Feedlot Initial C	70	Delta C	0.000	Feedlot Max C	446	Pack C	100

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Lot ID **Cell 4931**

Lot Area in Acres	**5.3**	**Upslope Area:**	**3.6**	**Duration:**	**180**	**Rating #:**	**53**
Feedlot Initial N	18	Delta N	0.102	Feedlot Max N	82	Pack N	100
Feedlot Initial P	8	Delta P	0.039	Feedlot Max P	25	Pack P	100
Feedlot Initial C	425	Delta C	2.377	Feedlot Max C	1292	Pack C	100

Lot ID **Cell 1473**

Lot Area in Acres	**1.5**	**Upslope Area:**	**8.2**	**Duration:**	**180**	**Rating #:**	**74**
Feedlot Initial N	0	Delta N	0.000	Feedlot Max N	117	Pack N	100
Feedlot Initial P	0	Delta P	0.000	Feedlot Max P	35	Pack P	100
Feedlot Initial C	0	Delta C	0.000	Feedlot Max C	1872	Pack C	100

Lot ID **Cell 822**

Lot Area in Acres	**1.5**	**Upslope Area:**	**8.2**	**Duration:**	**180**	**Rating #:**	**66**
Feedlot Initial N	19	Delta N	0.031	Feedlot Max N	45	Pack N	100
Feedlot Initial P	13	Delta P	0.012	Feedlot Max P	14	Pack P	100
Feedlot Initial C	367	Delta C	0.718	Feedlot Max C	847	Pack C	100

APPENDIX D

Medicine Creek Tributary Chemical Data for 2000 through 2001

Table D-1. Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Conductivity @ 25 µS/cm	Dissolved Oxygen mg/L	pH s.u.	Water Temperature °C	Fecal Coliform Bacteria (colonies/100 ml)	E. coli Bacteria (colonies/100 ml)	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	Volatile Total Suspended Solids mg/L
MCT-1	06/12/00		10.79	8.36	23.00			187	1,226	1,201	25	2
MCT-1	07/18/00	4,640		8.68	19.79	5,600		120	4,521	4,437	84	40
MCT-1	04/25/01	1,546	9.27	7.89	8.51	3,500	572	123	1,940	1,200	740	30
MCT-1	05/11/00		9.20	8.18	16.00	580		309	3,943	3,863	80	12
MCT-1	05/22/01	3,159	10.24	8.25	10.76	130	144	292	3,257	3,245	12	1
MCT-1	05/13/01	2,828	9.96	8.22	18.98	120	131	225	2,625	2,513	112	16
MCT-1	04/05/01	2,459	12.24	8.09	7.50	90	111	191	2,197	2,167	30	4
MCT-1	04/26/00		9.60	8.17	14.00	80		225	3,036	2,948	88	12
MCT-1	05/30/00		8.20		18.00	5		305	4,642	4,598	44	6
MCT-1	03/26/01	1,730	10.59	7.97	1.43	5	12	145	1,437	1,393	44	5
MCT-1	03/13/01	1,285	10.78	7.84	0.12	5		88	1,021	980	41	2
MCT-1A	06/12/00		8.18	8.06	23.10			184	1,062	1,034	28	2
MCT-1A	07/18/00					34,000		197	4,560	4,506	54	8
MCT-1A	04/25/01	1,223	8.97	8.01	8.87	2,600	1,410	137	1,735	895	840	60
MCT-1A	05/17/00		9.00	8.23	15.00	1,200		284	4,309	4,223	86	14
MCT-1A	05/22/01	3,085	9.80	8.21	12.85	400	260	278	2,876	2,870	6	1
MCT-1A	05/13/01	2,092	8.95	8.00	18.66	300	308	220	1,914	1,906	8	3
MCT-1A	05/13/01	2,092	8.95	8.00	18.66	290	179	217	1,909	1,899	10	1
MCT-1A	05/31/00		8.60	8.22	19.00	230		336	5,132	4,970	162	22
MCT-1A	05/11/00		9.50		17.00	230		268	3,714	3,654	60	8
MCT-1A	04/25/00		9.20	8.08	16.00	40		188	1,834	1,802	32	4
MCT-1A	04/05/01	2,342	11.12	8.02	7.25	30	32	190	2,260	2,245	15	1
MCT-1A	03/13/01	1,260	10.32	7.82	0.07	20		90	975	969	6	1
MCT-1A	03/27/01	1,432	9.91	7.97	1.36	10	19	143	1,172	1,138	34	5
MCT-2	04/25/01	1,235	9.05	8.07	7.73	2,200	756	108	1,141	949	192	1
MCT-2	06/29/00	3,060	10.98	8.08	19.00	2,200		247	2,800	2,763	37	5
MCT-2	06/02/00		8.69	8.09	15.68	1,000		294	3,654	3,620	34	3
MCT-2	07/18/00	2,955		8.06	20.25	520		207	2,640	2,629	11	4
MCT-2	05/22/01	3,202	10.39	8.20	13.52	200	120	277	5,950	5,931	19	3
MCT-2	05/22/01	3,202	10.39	8.20	13.52	150	148	280	2,952	2,936	16	2
MCT-2	03/27/01	782	11.51	7.85	1.13	50	55	136	1,252	1,188	64	8
MCT-2	04/26/00		9.50	8.21	14.00	40		216	2,851	2,777	74	12
MCT-2	03/13/01	392	11.17	7.91	1.02	40		88	1,021	998	23	3
MCT-2	05/13/01	2,613	12.10	8.43	19.72	30	186	212	2,409	2,395	14	1
MCT-2	04/05/01	2,244	11.82	8.00	7.55	20	18	183	2,012	1,970	42	7
MCT-3	04/25/01	474	9.05	8.07	8.64	3,100	1,990	78	1,230	410	820	30
MCT-3	04/12/01	563	12.44	7.89	3.27	2,700	2,420	82	760	465	295	40
MCT-3	03/13/01	65	10.96	8.40	0.42	130		19	82	77	5	4
MCT-3	04/26/00			7.70	14.00	30		137	1,040	1,040		7
MCT-3	03/26/01	524	9.41	7.76	1.31	5	3	75	417	393	24	5
MCT-3	04/05/01	757	10.62	7.92	7.12	5	2	91	597	591	6	2
MCT-4	07/18/00		4.87	7.82	12.20	5,700		288	702	572	130	20
MCT-4	04/12/01	604	13.68	7.90	3.31	100	58	111	456	400	56	4
MCT-4	04/25/01	357	10.27	7.94	4.66	80	126	81	758	318	440	70
MCT-4	05/13/01	604	3.94	8.11	16.62	30	13	174	443	441	2	1
MCT-4	05/22/01	692	7.38	8.42	11.10	30	23	233	509	507	2	1
MCT-4	03/26/01	432	9.66	7.98	0.74	20	1	82	328	320	8	3
MCT-4	03/19/01	227	10.84	7.91	3.24	10	20	50	253	193	60	6
MCT-4	04/05/01	571	8.73	7.92	7.09	10	2	110	434	429	5	2

Table D-1 (continued). Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Organic Nitrogen mg/L	Inorganic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Phosphorus mg/L	NP Ratio mg/L
MCT-1	06/12/00	0.01	0.001016	4.20	1.54	1.53	4.21	5.74	0.104	0.031	55.19
MCT-1	07/18/00	0.01	0.001577	18.20	2.02	2.01	18.21	20.22	0.278	0.029	72.73
MCT-1	04/25/01	0.10	0.001270	10.40	2.14	2.04	10.50	12.54	1.360	0.092	9.22
MCT-1	05/11/00	0.05	0.002139	14.30	2.95	2.90	14.35	17.25	0.193	0.067	89.38
MCT-1	05/22/01	0.01	0.000340	5.80	1.63	1.62	5.81	7.43	0.054	0.026	137.59
MCT-1	05/13/01	0.01	0.000576	7.40	1.66	1.65	7.41	9.06	0.076	0.034	119.21
MCT-1	04/05/01	0.01	0.000185	24.00	1.49	1.48	24.01	25.49	0.151	0.059	168.81
MCT-1	04/26/00	0.01	0.000362	20.50	2.65	2.64	20.51	23.15	0.228	0.030	101.54
MCT-1	05/30/00	0.01	0.000000	27.10	2.46	2.45	27.11	29.56	0.117	0.113	252.65
MCT-1	03/26/01	0.32	0.002760	12.50	1.95	1.63	12.82	14.45	0.262	0.156	55.15
MCT-1	03/13/01	0.22	0.001264	19.00	3.19	2.97	19.22	22.19	0.339	0.185	65.46
MCT-1A	06/12/00	0.01	0.000540	4.40	1.42	1.41	4.41	5.82	0.127	0.032	45.83
MCT-1A	07/18/00	0.01	0.000000	37.50	2.04	2.03	37.51	39.54	0.128	0.034	308.91
MCT-1A	04/25/01	0.09	0.001543	11.60	1.74	1.65	11.69	13.34	0.321	0.071	41.56
MCT-1A	05/17/00	0.08	0.003555	34.80	2.49	2.41	34.88	37.29	0.206	0.022	181.02
MCT-1A	05/22/01	0.01	0.000363	30.90	2.25	2.24	30.91	33.15	0.054	0.025	613.89
MCT-1A	05/13/01	0.01	0.000347	17.50	1.34	1.33	17.51	18.84	0.048	0.032	392.50
MCT-1A	05/13/01	0.01	0.000347	17.10	1.50	1.49	17.11	18.60	0.050	0.028	372.00
MCT-1A	05/31/00	0.01	0.000577	54.80	2.53	2.52	54.81	57.33	0.090	0.002	637.00
MCT-1A	05/11/00	0.02	0.000000	36.50	2.02	2.00	36.52	38.52	0.130	0.034	296.31
MCT-1A	04/25/00	0.01	0.000343	21.90	2.11	2.10	21.91	24.01	0.138	0.029	173.99
MCT-1A	04/05/01	0.01	0.000155	43.70	1.64	1.63	43.71	45.34	0.107	0.066	423.74
MCT-1A	03/13/01	0.18	0.000984	23.10	2.69	2.51	23.28	25.79	0.238	0.174	108.36
MCT-1A	03/27/01	0.34	0.002915	16.90	2.04	1.70	17.24	18.94	0.230	0.132	82.35
MCT-2	04/25/01	0.04	0.000719	5.80	1.22	1.18	5.84	7.02	0.532	0.120	13.20
MCT-2	06/29/00	0.10	0.004249	15.10	1.98	1.88	15.20	17.08	0.114	0.020	149.82
MCT-2	06/02/00	0.02	0.000685	5.90	2.15	2.13	5.92	8.05	0.104	0.025	77.40
MCT-2	07/18/00	0.01	0.000444	2.00	1.17	1.16	2.01	3.17	0.057	0.014	55.61
MCT-2	05/22/01	0.03	0.001120	3.30	1.53	1.50	3.33	4.83	0.082	0.031	58.90
MCT-2	05/22/01	0.01	0.000373	3.30	1.39	1.38	3.31	4.69	0.083	0.020	56.51
MCT-2	03/27/01	0.30	0.001918	10.40	1.69	1.39	10.70	12.09	0.261	0.132	46.32
MCT-2	04/26/00	0.01	0.000395	17.90	2.64	2.63	17.91	20.54	0.209	0.033	98.28
MCT-2	03/13/01	0.23	0.001672	21.00	2.79	2.56	21.23	23.79	0.274	0.178	86.82
MCT-2	05/13/01	0.01	0.000948	8.90	1.50	1.49	8.91	10.40	0.065	0.041	160.00
MCT-2	04/05/01	0.01	0.000151	19.60	1.39	1.38	19.61	20.99	0.178	0.081	117.92
MCT-3	04/25/01	0.07	0.001350	0.40	0.76	0.69	0.47	1.16	1.450	0.202	0.80
MCT-3	04/12/01	0.04	0.000334	1.00	0.69	0.65	1.04	1.69	0.708	0.212	2.39
MCT-3	03/13/01	0.01	0.000211	0.30	1.29	1.28	0.31	1.59	0.322	0.253	4.94
MCT-3	04/26/00	0.02	0.000251	0.10	1.48	1.46	0.12	1.58	0.121	0.034	13.06
MCT-3	03/26/01	0.03	0.000158	0.60	0.56	0.53	0.63	1.16	0.303	0.248	3.83
MCT-3	04/05/01	0.02	0.000244	0.10	0.59	0.57	0.12	0.69	0.221	0.168	3.12
MCT-4	07/18/00	0.03	0.000432	0.90	1.45	1.42	0.93	2.35	0.887	0.536	2.65
MCT-4	04/12/01	0.02	0.000172	1.40	1.01	0.99	1.42	2.41	0.282	0.181	8.55
MCT-4	04/25/01	0.03	0.000314	0.90	1.35	1.32	0.93	2.25	0.902	0.250	2.49
MCT-4	05/13/01	0.01	0.000383	0.10	0.82	0.81	0.11	0.92	0.180	0.117	5.11
MCT-4	05/22/01	0.01	0.000507	0.10	0.99	0.98	0.11	1.09	0.188	0.127	5.80
MCT-4	03/26/01	0.01	0.000083	0.90	0.55	0.54	0.91	1.45	0.317	0.284	4.57
MCT-4	03/19/01	0.18	0.001570	1.10	1.32	1.14	1.28	2.42	0.537	0.400	4.51
MCT-4	04/05/01	0.01	0.000122	0.10	0.61	0.60	0.11	0.71	0.220	0.179	3.23

Table D-1 (continued). Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Conductivity @ 25 µS/cm	Dissolved Oxygen mg/L	pH s.u.	Water Temperature °C	Fecal Coliform Bacteria (colonies/100 ml)	E. coli Bacteria (colonies/100 ml)	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	Volatile Total Suspended Solids mg/L
MCT-5	04/12/01	604	13.14	7.87	2.63	130	157	94	539	457	82	20
MCT-5	04/25/01	499	10.01	7.81	7.49	70	65	84	452	372	80	14
MCT-5	03/19/01	277	10.11	8.11	2.23	10	2	72	205	188	17	7
MCT-5	04/05/01	792	7.18	7.96	6.62	10	11	134	606	603	3	2
MCT-5	04/26/00		9.80	8.14	15.00	5		194	2,011	1,985	26	9
MCT-6	04/12/01	558	13.68	7.90	2.80	1,400	548	114	1,210	440	770	70
MCT-6	04/26/01	486	6.29	7.86	14.19	200	365	113	576	380	196	24
MCT-6	03/19/01		5.71	8.12	2.50	5	3	50	149	137	12	4
MCT-7	04/25/01	412	9.36	7.96	4.99	6,100	2,420	84	1,138	338	800	40
MCT-7	07/18/00	1,346	6.70	8.17	20.20	1,700		183	1,099	1,031	68	14
MCT-7	04/25/00		9.10	7.66	15.00	400		139	1,074	1,030	44	6
MCT-7	03/19/01	277	10.11	8.11	2.23	20	6	55	354	230	124	10
MCT-7	05/22/01	754	5.33	8.33	13.94	5	9	213	657	574	83	10
MCT-7	05/22/01	754	5.33	8.33	13.94	5	10	214	658	581	77	8
MCT-7	05/13/01	671	8.80	8.11	21.35	5	10	166	511	491	20	2
MCT-7	04/05/01	641	11.18	8.18	6.72	5	4	105	491	483	8	3
MCT-8	04/26/01	480	11.85	8.51	10.33	80	93	111	388	341	47	8
MCT-8	05/13/01	476	8.82	8.26	17.23	5	1	122	381	368	13	1
MCT-9	04/25/01	532	9.41	7.94	2.86	4,700	2,420	120	2,128	368	1,760	80
MCT-9	06/14/00	4,000	8.12	8.33	18.31	2,200		217	3,781	3,709	72	6
MCT-9	07/18/00		8.20	8.19	20.70	550		169	3,889	3,817	72	12
MCT-9	06/01/00	4,000	11.60	8.38	17.80	470		283	4,066	3,728	338	20
MCT-9	03/13/01	1,767	10.42	7.93	0.15	190		123	1,440	1,380	60	18
MCT-9	06/21/00	3,810	9.13	8.37	16.70	160		240	3,506	3,452	54	5
MCT-9	05/13/01	2,313	16.37	8.80	22.03	130	108	189	2,062	1,990	72	4
MCT-9	05/23/01	2,671	13.90	8.52	11.04	130	111	240	2,442	2,422	20	2
MCT-9	04/27/00		9.30	8.35	15.00	100		202	2,596	2,508	88	16
MCT-9	03/26/01	1,114	10.73	7.58	0.50	70	79	114	903	833	70	4
MCT-9	03/19/01		10.08	7.99	1.37	40	65	94	1,109	479	630	50
MCT-9	06/29/00	4,000	12.46	8.45	19.50	40		208	3,780	3,696	84	10
MCT-9	04/05/01	1,405	11.31	8.13	6.81	10	28	141	1,150	1,120	30	5
MCT-9	04/20/00		9.80	8.36	15.00	5		172	5,012	4,880	132	12
MCT-10	05/23/01	362	13.66	8.90	11.95	80	22	123	244	213	31	4
MCT-10	05/13/01	302	10.47	8.56	20.28	20	25	116	243	214	29	2
MCT-10	05/23/01	362	13.66	8.90	11.95	5	17	123	245	220	25	3
MCT-11	04/12/01	240	14.30	8.02	2.26	20	22	88	301	199	102	4
MCT-11	04/25/01	148	11.81	8.13	5.09	5	40	66	151	122	29	3
MCT-11	03/13/01	490	10.96	8.65	0.63	5		11	63	56	7	1
MCT-12	04/25/01	314	6.85	7.85	3.77	29,000	2,420	113	401	303	98	12
MCT-12	07/11/00	200	1.63	7.86	20.11	23,000		75	613	381	232	16
MCT-12	05/13/01	365	4.32	8.19	16.48	100	30	183	304	247	57	3
MCT-12	03/20/01	247	8.54	7.95	6.32	5	4	74	269	218	51	4

Table D-1 (continued). Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Organic Nitrogen mg/L	Inorganic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Solids mg/L	NP Ratio mg/L
MCT-5	04/12/01	0.07	0.000530	5.90	1.32	1.25	5.97	7.22	0.564	0.378	12.80
MCT-5	04/25/01	0.09	0.000879	4.10	0.85	0.76	4.19	4.95	0.447	0.298	11.07
MCT-5	03/19/01	0.23	0.002914	0.80	1.36	1.13	1.03	2.16	0.337	0.275	6.41
MCT-5	04/05/01	0.01	0.000128	7.70	0.97	0.96	7.71	8.67	0.345	0.312	25.13
MCT-5	04/26/00	0.01	0.000364	24.30	3.26	3.25	24.31	27.56	0.214	0.101	128.79
MCT-6	04/12/01	0.28	0.002303	4.90	1.27	0.99	5.18	6.17	1.410	0.294	4.38
MCT-6	04/26/01	0.06	0.001099	3.40	1.76	1.70	3.46	5.16	0.621	0.306	8.31
MCT-6	03/19/01	0.26	0.003445	0.60	1.29	1.03	0.86	1.89	0.565	0.479	3.35
MCT-7	04/25/01	0.15	0.001690	0.60	1.79	1.64	0.75	2.39	1.480	0.222	1.61
MCT-7	07/18/00	0.01	0.000563	0.10	0.95	0.94	0.11	1.05	0.162	0.038	6.48
MCT-7	04/25/00	0.01	0.000124	1.20	1.16	1.15	1.21	2.36	0.275	0.151	8.58
MCT-7	03/19/01	0.20	0.002534	0.90	1.27	1.07	1.10	2.17	0.610	0.332	3.56
MCT-7	05/22/01	0.03	0.001537	0.10	0.86	0.83	0.13	0.96	0.115	0.048	8.35
MCT-7	05/22/01	0.03	0.001537	0.10	0.87	0.84	0.13	0.97	0.266	0.064	3.65
MCT-7	05/13/01	0.01	0.000534	0.10	0.72	0.71	0.11	0.82	0.156	0.172	5.26
MCT-7	04/05/01	0.01	0.000213	0.10	0.74	0.73	0.11	0.84	0.215	0.154	3.91
MCT-8	04/26/01	0.01	0.000583	2.00	0.93	0.92	2.01	2.93	0.240	0.128	12.21
MCT-8	05/13/01	0.12	0.006677	1.60	1.15	1.03	1.72	2.75	0.141	0.111	19.50
MCT-9	04/25/01	0.43	0.003895	1.00	1.88	1.45	1.43	2.88	2.820	0.193	1.02
MCT-9	06/14/00	0.03	0.002093	4.90	1.94	1.91	4.93	6.84	0.160	0.031	42.75
MCT-9	07/18/00	0.01	0.000608	0.10	1.15	1.14	0.11	1.25	0.186	0.044	6.72
MCT-9	06/01/00	0.07	0.005247	7.80	2.43	2.36	7.87	10.23	0.548	0.032	18.67
MCT-9	03/13/01	1.86	0.013163	24.00	6.63	4.77	25.86	30.63	0.997	0.626	30.72
MCT-9	06/21/00	0.07	0.004760	0.70	1.42	1.35	0.77	2.12	0.176	0.030	12.05
MCT-9	05/13/01	0.01	0.002251	5.80	2.27	2.26	5.81	8.07	0.164	0.045	49.21
MCT-9	05/23/01	0.01	0.000627	4.20	1.60	1.59	4.21	5.80	0.055	0.026	105.45
MCT-9	04/27/00	0.01	0.000578	16.10	2.92	2.91	16.11	19.02	0.223	0.146	85.29
MCT-9	03/26/01	0.24	0.000784	6.40	0.99	0.75	6.64	7.39	0.310	4.000	23.84
MCT-9	03/19/01	0.34	0.003054	3.70	1.80	1.46	4.04	5.50	1.330	0.638	4.14
MCT-9	06/29/00	0.01	0.000974	0.10	1.60	1.59	0.11	1.70	0.179	0.023	9.50
MCT-9	04/05/01	0.03	0.000574	8.60	1.11	1.08	8.63	9.71	0.197	0.124	49.29
MCT-9	04/20/00	0.07	0.004132	35.20	2.87	2.80	35.27	38.07	0.292	0.116	130.38
MCT-10	05/23/01	0.01	0.001469	0.30	0.81	0.80	0.31	1.11	0.112	0.061	9.91
MCT-10	05/13/01	0.09	0.011549	0.40	0.73	0.64	0.49	1.13	0.157	0.109	7.20
MCT-10	05/23/01	0.01	0.001469	0.30	0.81	0.80	0.31	1.11	0.114	0.060	9.74
MCT-11	04/12/01	0.04	0.000414	0.80	0.82	0.78	0.84	1.62	0.412	0.174	3.93
MCT-11	04/25/01	0.01	0.000167	0.50	0.37	0.36	0.51	0.87	0.235	0.194	3.70
MCT-11	03/13/01	0.62	0.023239	0.80	2.17	1.55	1.42	2.97	0.390	0.345	7.62
MCT-12	04/25/01	0.15	0.001191	0.50	2.13	1.98	0.65	2.63	1.660	1.320	1.58
MCT-12	07/11/00	0.11	0.003101	2.30	1.73	1.62	2.41	4.03	0.822	0.273	4.90
MCT-12	05/13/01	0.01	0.000453	0.10	1.30	1.29	0.11	1.40	0.175	0.101	8.00
MCT-12	03/20/01	0.48	0.005878	4.40	1.94	1.46	4.88	6.34	0.736	0.617	8.61

Table D-1 (continued). Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Conductivity @ 25 µS/cm	Dissolved Oxygen mg/L	pH s.u.	Water Temperature °C	Fecal Coliform Bacteria (colonies/100 ml)	E. coli Bacteria (colonies/100 ml)	Alkalinity mg/L	Total Solids mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	Volatile Total Suspended Solids mg/L
MCT-13	04/25/01	1,062	5.02	7.81	5.33	150,000	2,420	157	1,854	794	1,060	60
MCT-13	07/10/00	3,970	5.36	7.81	24.60	4,800		138	3,758	3,668	90	16
MCT-13	03/19/01	813	10.51	7.91	0.80	3,200	687	122	1,705	485	1,220	120
MCT-13	06/14/00	4,000	9.33	8.61	20.60	1,300		142	3,825	3,772	53	12
MCT-13	05/23/01	2,287	14.88	8.45	12.11	250	185	201	2,100	2,074	26	2
MCT-13	05/14/01	1,653	16.71	8.93	21.56	200	158	177	1,464	1,348	116	16
MCT-13	07/18/00	4,630	4.70	8.39	21.23	200		145	4,379	4,315	64	22
MCT-13	06/21/00	4,200	8.48	8.29	20.50	180		152	3,942	3,824	118	12
MCT-13	06/01/00	3,920	10.75	8.49	19.30	160		199	3,652	3,607	45	6
MCT-13	04/26/00		9.40	8.23	15.00	86		194	2,676	2,538	138	18
MCT-13	03/13/01	2,635	10.36	8.00	0.08	30		159	2,114	2,102	12	5
MCT-13	03/26/01	1,119	10.78	7.94	0.92	10	86			0		
MCT-13	04/12/00		11.00		15.00	5		188	4,822	4,757	65	11
MCT-13	04/05/01	1,333	10.79	7.99	6.34	5	27	136	1,095	1,045	50	8
MCT-14	04/26/01	398	10.23	8.22	9.41	1,600	1,550	88	392	306	86	8
MCT-14	04/12/01	533	12.48	7.85	3.04	380	326	109	675	405	270	20
MCT-14	05/13/01	896	9.60	8.56	22.53	30	13	165	688	666	22	3
MCT-14	03/19/01	267	11.01	7.95	0.62	10	56	51	277	205	72	10
MCT-14	05/13/01	444	11.32	8.60	16.14	5	1	113	372	331	41	4
MCT-14	05/13/01	444	11.32	8.60	16.14	5	2	105	373	334	39	7
MCT-14	03/26/01	629	8.01	7.97	0.58	5	4	87	486	467	19	1
MCT-14	04/05/01	747	8.40	7.95	6.44	5	4	130	567	559	8	3
MCT-14	03/13/01	827	7.47	8.37	0.19	5		70	582	578	4	2
MCT-15	04/26/01	398	10.23	8.22	9.41	1,600		88	392	306	86	8
MCT-15	05/13/01	444	11.23	8.60	16.14	5		105	373	334	39	7
MCT-15	04/10/01	583	12.99	8.43	5.99	5		118	442	417	25	9
MCT-15	05/15/01	447	9.96	8.80	16.66	5		115	355	332	23	4

Table D-1 (continued). Chemical data Medicines Creek, Lyman and Jones Counties, South Dakota from 2000 through 2001.

Site	Date	Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Organic Nitrogen mg/L	Inorganic Nitrogen mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Total Dissolved Solids mg/L	NP Ratio mg/L
MCT-13	04/25/01	0.84	0.006908	2.20	3.84	3.00	3.04	6.04	2.600	0.616	2.32
MCT-13	07/10/00	0.23	0.007931	0.50	1.59	1.36	0.73	2.09	0.310	0.031	6.74
MCT-13	03/19/01	0.54	0.003854	5.20	1.89	1.35	5.74	7.09	1.490	0.165	4.76
MCT-13	06/14/00	0.01	0.001446	1.80	2.18	2.17	1.81	3.98	0.167	0.034	23.83
MCT-13	05/23/01	0.02	0.001166	7.90	1.11	1.09	7.92	9.01	0.060	0.016	150.17
MCT-13	05/14/01	0.01	0.002747	3.00	1.47	1.46	3.01	4.47	0.212	0.045	21.08
MCT-13	07/18/00	0.01	0.000964	0.10	1.59	1.58	0.11	1.69	0.183	0.036	9.23
MCT-13	06/21/00	0.11	0.008180	1.20	1.52	1.41	1.31	2.72	0.254	0.032	10.71
MCT-13	06/01/00	0.01	0.001044	6.00	2.33	2.32	6.01	8.33	0.117	0.022	71.20
MCT-13	04/26/00	0.01	0.000444	18.30	2.22	2.21	18.31	20.52	0.306	0.035	67.06
MCT-13	03/13/01	0.67	0.005531	9.50	2.99	2.32	10.17	12.49	0.140	0.071	89.21
MCT-13	03/26/01	0.42	0.003242	5.30	1.49	1.07	5.72	6.79	0.480	0.288	14.15
MCT-13	04/12/00	0.01	0.000000	33.90	3.11	3.10	33.91	37.01	0.106	0.016	349.15
MCT-13	04/05/01	0.06	0.000806	6.90	0.93	0.87	6.96	7.83	0.219	0.100	35.75
MCT-14	04/26/01	0.13	0.003728	1.50	1.24	1.11	1.63	2.74	0.463	0.226	5.92
MCT-14	04/12/01	0.04	0.000299	1.40	0.76	0.72	1.44	2.16	0.651	0.245	3.32
MCT-14	05/13/01	0.01	0.001477	0.10	1.14	1.13	0.11	1.24	0.134	0.074	9.25
MCT-14	03/19/01	0.35	0.002696	1.00	1.27	0.92	1.35	2.27	0.510	0.306	4.45
MCT-14	05/13/01	0.02	0.002124	1.00	1.08	1.06	1.02	2.08	0.236	0.155	8.81
MCT-14	05/13/01	0.01	0.001062	1.00	0.95	0.94	1.01	1.95	0.249	0.157	7.83
MCT-14	03/26/01	0.14	0.001125	2.30	0.73	0.59	2.44	3.03	0.380	0.327	7.97
MCT-14	04/05/01	0.01	0.000124	1.90	0.70	0.69	1.91	2.60	0.261	0.247	9.96
MCT-14	03/13/01	0.20	0.003863	0.70	1.41	1.21	0.90	2.11	0.268	0.212	7.87
MCT-15	04/26/01	0.13	0.003730	1.50	1.24	1.11	1.63	2.74	0.463	0.226	5.92
MCT-15	05/13/01	0.01	0.001060	1.00	0.95	0.94	1.01	1.95	0.249	0.157	7.83
MCT-15	04/10/01	0.01	0.000090	0.90	0.18	0.91	1.08	0.17	0.187	0.106	0.91
MCT-15	05/15/01	0.08	0.013100	0.90	1.33	1.25	0.98	2.23	0.217	0.129	10.28

APPENDIX E

Benthic Macroinvertebrate Summary Report

BENTHIC MACROINVERTEBRATE IDENTIFICATION SUMMARY REPORT

for

MEDICINE CREEK, SOUTH DAKOTA

2002

Prepared for the

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September, 2002

INTRODUCTION

Benthic macroinvertebrate populations are known to be key indicators of stream ecosystem health (Hynes 1960). Life spans for some of these creatures are as long as three years, and their complex life cycles and limited mobility mean that there is ample time for the community to respond to cumulative effects of environmental perturbations. The analysis of macroinvertebrate communities can thus be related to a stream's biological health, or integrity, defined by Karr and Dudley (1981) as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitat of the region."

The multimetric approach to bioassessment using benthic macroinvertebrates uses attributes of the assemblage in an integrated way to reflect overall biotic condition. Community attributes, which can contribute meaningfully to bioassessment, include assemblage structure, sensitivity of community members to stress or pollution, and functional traits. Each metric component contributes an independent measure of the biotic integrity of a stream site.

METHODS

Benthic macroinvertebrate samples were collected by personnel of the South Dakota Department of Environment and Natural Resources (SD-DENR) from Medicine Creek, South Dakota, on October 17, 2001. Three replicate samples were collected from three sites, resulting in a total of nine samples, as follows:

1. MC 02, reps 1, 2 and 3
2. MC 09, reps 1, 2 and 3
3. MC 13, reps 1, 2 and 3

Macroinvertebrate Sample Processing and Identification

Laboratory sample processing, benthic macroinvertebrate taxonomic identifications, data compilation and metrics computations were contracted by the SD-DENR to Natural Resource Solutions. The benthic macroinvertebrate samples were processed and identified using the U.S. Environmental Protection Agency’s techniques for RBP III (Plafkin et al.1989), and the SD-DENR’s SOP.

Sample processing consisted of obtaining approximately a 300-organism subsample. Organisms were then enumerated and identified whenever possible to the taxonomic level specified in the SD-DENR’s SOP. The SOP requirements for subsampling and taxonomic resolution were strictly adhered to, deviating only when the quality of the specimen was lacking due either to immaturity, or missing body parts needed for identification. In either case, when organisms could not be confidently taken to the taxonomic level outlined in the SOP, they were more conservatively identified. Taxonomic identification of the Chironomidae and Oligochaeta were subcontracted by Natural Resource Solutions to Michael McBride. Following is a description of the subsampling procedure: Each sample was rinsed in a 0.30 mm sieve to remove preservative. The washed sample was then transferred to an appropriately sized invertebrate sorting tray marked into square quadrants. Water was added to the tray to allow complete dispersion of the sample and even distribution of the organisms. Quadrants were randomly selected and organisms removed from each quadrant until the total number of organisms fell within the range of 270 to 330 (±10% of 300 organisms), or until there were no more invertebrates to remove, whichever occurred first.

Data Analysis

Community structure, function and sensitivity to impact were characterized for each sample, using whenever possible a battery of 42 metrics requested by the SD-DENR. The data was entered into an Excel spreadsheet, and also into the "Ecological Data Analysis System (EDAS), a metrics analysis program designed by TetraTech which functions within the Microsoft Access database. Many of the desired metrics were automatically computed by the EDAS program, however some others that were not included in the EDAS program had to be computed manually by Natural Resource Solutions.

RESULTS

Site 2:

This site showed some signs of better health overall than the other two sites. This site had the highest taxa richness of all three sites, and the greatest number of Ephemeroptera taxa and percent Coleoptera of all three sites. This site also had the lowest percent Chironomidae and percent other Diptera, usually groups that signify lower water quality. Site 2, for all three replicates, had high numbers of *Hyalella azteca*, which gives a mixed message. This species is known to be sediment tolerant, however, the Amphipoda in general require an abundance of dissolved oxygen and are usually found in unpolluted waters. The amphipod *Hyalella azteca* was by far the dominant taxon for this site. All three sites had very high percentages of tolerant organisms, however, Site 2 had greater numbers of intolerant taxa than the other two sites, for all three replicates (3, 1 and 2, respectively). All three sites also had high percentages of dominant taxa, generally indicative of impairment. This site had a fairly high Hilsenhoff Biotic Index for all three replicates, as well as a very high percentage of collector-gatherers (70%, averaged for three replicates) and gatherers + filterers (71%); these results are generally considered to be indicative of lower water quality, most likely caused by organic enrichment. However, this site also had lower numbers of sediment tolerant organisms and greater numbers of predator taxa than did the other two sites, usually indicative of better water quality.

Taking into account the aforementioned results, mild organic enrichment may be limiting the biotic integrity somewhat at this site, however, this site shows less impairment overall than the other two sites. As a summary for this site, it appears to less impaired when compared to the other two sites in this sampling effort, with a tolerant benthic macroinvertebrate community overall.

Site 9:

By far the dominant taxon for this site was *Caenis* sp., an Ephemeropteran (Mayfly) known to be tolerant, especially to high degrees of sedimentation. The taxa richness for two of the replicates was fairly low, but replicate 3 had a relatively high taxa richness of 28. Two of the replicates showed a healthy diversity of Coleoptera taxa, however, all three replicates had very high numbers of Diptera and Chironomidae taxa. The EPT taxa and the percent EPT metrics, and any others associated with the EPT metric (EPT/Chironomidae, for example) cannot be relied upon as good indicators for this site, due to the fact that the dominant taxon was *Caenis* sp., a tolerant Ephemeropteran. The extremely high numbers of *Caenis* sp. have caused the EPT taxa and percent EPT metrics to appear high (usually a good indicator of stream health), however in this case, it is not. As with all three sites, this site had high percentages of tolerant organisms, and very low numbers of intolerant taxa for all three replicates (0, 1 and 1, respectively). This site, as with all three sites, had a high percentage of dominant taxa. This site had a marginal Hilsenhoff Biotic Index of 6.6, generally indicative of mild impairment. This site also had a high percentage of collector-gatherers (65%, averaged for the three replicates) and gatherers+filterers (66%, averaged for the three replicates); these results are generally considered to be indicative of lower water quality and mild impairment, most likely caused by organic enrichment.

As a summary for this site, it appears to have slight-to-moderate impairment, where significant organic enrichment may be limiting the biotic integrity at this site. From the sampled assemblage, this site appears to have a tolerant benthic macroinvertebrate community overall, particularly to organic pollution.

Site 13:
On most accounts, this site was remarkably similar to site 9, however of the three sites, this site showed the greatest degree of impairment overall in this sampling effort. As with site 9, the dominant taxon for this site by far was *Caenis* sp., a highly sediment tolerant Ephemeropteran. The taxa richness scores for this site for all three replicates were quite low, at 20, 18 and 20, respectively. This site had very few to no Coleoptera taxa, and very high numbers of Diptera and Chironomidae taxa. As was the case for site 9, the EPT taxa, the percent EPT and any metric associated with the EPT metric (EPT/Chironomidae, for example) cannot be relied upon as good indicators for this site, due to the fact that the dominant taxon was *Caenis* sp., a very tolerant Ephemeropteran. These extremely high numbers of *Caenis* sp. have caused the EPT taxa and percent EPT to appear high (usually a good indicator of stream health), however in this case, it is not, as with site 9. Site 13 had very high percentages of tolerant organisms (56%, 80% and 84%, respectively), and low numbers of intolerant taxa for all three replicates (1, 0 and 2, respectively). This site, as with all three sites, had a high percentage of dominant taxa. This site had a higher Hilsenhoff Biotic Index of 7.1, generally indicative of moderate impairment. This site also had a very high percentage of collector-gatherers (77%, averaged for three replicates) and gatherers + filterers (80%); these results are generally considered to be indicative of lower water quality and moderate impairment, in this case most likely caused by organic enrichment.

In summary, this site appears to have moderate impairment, where significant organic enrichment may be limiting the biotic integrity. Organic pollution and excessive sedimentation is strongly suggested by the data. High water temperatures, probably associated with low flows, may also have impacted the benthic community here. From the sampled assemblage, this site appears to have a highly tolerant benthic community overall, particularly to organic pollution and excessive fine sediments.

LITERATURE CITED

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APPENDIX F

Rare, Threatened and Endangered Species Documented in the Medicine Creek Watershed, Lyman and Jones Counties, South Dakota as of December 2002

Key to Codes Used in Natural Heritage Database Reports

FEDERAL STATUS	LE = Listed endangered LT = Listed threatened LELT = Listed endangered in part of range, threatened in part of range PE = Proposed endangered PT = Proposed threatened C = Candidate for federal listing, information indicates that listing is justified.
STATE STATUS	SE = State Endangered ST = State Threatened

An endangered species is a species in danger of extinction throughout all or a significant portion of its range. (applied range wide for federal status and statewide for state status)

A threatened species is a species likely to become endangered in the foreseeable future.

Global Rank	State Rank	Definition (applied rangewide for global rank and statewide for state rank)
G1	S1	Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	S2	Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3	S3	Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences.
G4	S4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.
G5	S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
GU	SU	Possibly in peril, but status uncertain, more information needed.
GH	SH	Historically known, may be rediscovered.
GX	SX	Believed extinct, historical records only.
G?	S?	Not yet ranked
_?	_?	Inexact rank
_T		Rank of subspecies or variety
_Q		Taxonomic status is questionable, rank may change with taxonomy
	SZ	No definable occurrences for conservation purposes, usually assigned to migrants
	SP	Potential exists for occurrence in the state, but no occurrences
	SR	Element reported for the state but no persuasive documentation
	SA	Accidental or casual

Bird species may have two state ranks, one for breeding (S#B) and one for nonbreeding seasons (S#N). Example: Ferruginous Hawk (S3B, SZN) indicates an S3 rank in breeding season and SZ in nonbreeding season.

Rare, Threatened or Endangered Species Documented in Medicine Creek and Medicine Creek Watershed HUC 10140104
South Dakota Natural Heritage Database
12//9/2002

NAME	TOWNSHIP RANGE & SECTION	COUNTY	LAST OBSERVED	FEDERAL STATUS	STATE STATUS	STATE RANK	GLOBAL RANK	EODATA
WHOOPING CRANE *Grus americana*	107N079W 11	Lyman	1997-10-29	LE	SE	SZN	G1	3 CRANES FLYING
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE NESTING PAIR, ONE JUVENILE OWL IN JULY.
SWAINSON'S HAWK *Buteo swainsoni*	108N079W 33	Lyman	1994		S4B	SZN	G5	ACTIVE NET IN 1994
FERRUGINOUS HAWK *Buteo regalis S*	107N079W 11	Lyman	1999-04-09		S4B	SZN	G4	ADULT SITTING ON NEST IN 1994. 1998-ON NEST, SAME LOCATION, ON APRIL 16 AND 30. ON NEST ON APRIL 9, 1999.
SWAINSON'S HAWK *Buteo swainson*	107N078W 27	Lyman	1999-04-28		S4B	SZN	G5	SWAINSON'S HAWK AT NEST
BURROWING OWL *Athene cunicularia*	107N078W 21	Lyman	1999-07-15		S3S4B	SZN	G4	FOUR ACTIVE OWL NESTS, ONE JUVENILE OWL IN JULY. 1999-2 BURROWING OWLS REPORTED IN THIS DOG TOWN.
BURROWING OWL *Athene cunicularia*	001N031E 33	Jones	1998-07		S3S4B	SZN	G4	THREE ACTIVE NESTS, 4+ JUVENILES IN JULY.
PLAINS SPOTTED SKUNK *Spilogale putorius interrup*	001S031E 32	Jones	1993-04-05		S3		G5T4	ROAD KILL
BAIRD'S SPARROW *Ammodramus bairdii*	001N031E 9	Jones	1997-08-29		S2B	SZN	G4	AT LEAST 2 SINGING IN THIS AREA, PRESENT ALL SUMMER
BURROWING OWL *Athene cunicularia*	107N079W 34	Lyman	1998-07		S3S4B	SZN	G4	ONE ACTIVE NEST, 2 JUVENILE OWLS IN JULY.
SPRAGUE'S PIPIT *Anthus spragueii*	107N078W 7	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST TWO SINGING IN SECTION 7, OTHERS HEARD IN SECTIONS 16 AND 17. HEARD IN AREA ALL SUMMER.
BAIRD'S SPARROW *Ammodramus bairdi*	107N078W 9	Lyman	1997-07-29		S2B	SZN	G4	AT LEAST FIVE SEEN OR HEARD, OTHERS IN SECTION 8 TO THE WEST AND IN SEC. 26 T108N R78W. PRESENT IN THESE AREAS ALL SUMMER.
WHOOPING CRANE *Grus Americana*	105N076W 31	Lyman	1998-05-07	LE	SE	SZN	G1	ONE CRANE ON GROUND FOR 5 DAYS

APPENDIX G

Medicine Creek Total Maximum Daily Load Document

TOTAL MAXIMUM DAILY LOAD EVALUATION

For

TOTAL SUSPENDED SOLIDS (TSS)
AND
FECAL COLIFORM BACTERIA
In

MEDICINE CREEK WATERSHED

(HUC 10140104)

LYMAN and JONES COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

AUGUST, 2005

Medicine Creek Total Maximum Daily Load August, 2005

Waterbody Type:	River/Stream
303(d) Listing Parameters:	Total Suspended Solids (TSS) and Fecal Coliform
Designated Uses:	Warmwater marginal fish life propagation water; Limited contact recreation waters; Fish and wildlife propagation, recreation and stock watering water. Irrigation water
Size of Waterbody:	121.7 stream kilometers (75.6 stream miles)
Size of Watershed:	157,860 hectare (390,072 acres)
Water Quality Standards:	Numeric
Indicators:	Sediment concentrations (mg/L) Fecal coliform Bacteria (cfu/100 ml)
Analytical Approach:	FLUX and AnnAGNPS
Location:	HUC Code: 10140104
TMDL Goal	
Total Suspended Solids:	20.1% reduction in TSS (5,053,480 kg/year)
Fecal Coliform Bacteria	18.3% reduction in fecal coliform (7.50×10^{12} cfu/fecal season)
TMDL Target	
Total Suspended Solids:	$\leq$ 263 mg/L for any one grab sample or (20,172,490 kg/year)
Fecal Coliform Bacteria	$\leq$ 2,000 cfu/100 ml any one grab sample from May 1 through September 30 or (3.89×10^{13} cfu/fecal season)

Objective:

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

Figure 1. Medicine Creek watershed location in South Dakota.

Medicine Creek is a 157,860 hectare (390,072-acre) watershed located in Lyman and Jones Counties, South Dakota (Figure 1). Medicine Creek is listed in the 2004 South Dakota Integrated Report for Surface Water Quality (combined 303(d) and 305(b) reports) for conductivity and total dissolved solids (TDS). Elevated conductivity and total dissolved solids appear to be caused by the geological makeup of Pierre Shale contributing increased TDS concentrations resulting in increased conductivity values during low flow conditions. During the assessment, (TSS) total suspended solids and fecal coliform bacteria also exceeded water quality standards and required TMDLs. Watershed modeling indicated that Medicine Creek could meet current water quality standards for TSS and fecal coliform. AnnAGNPS tributary modeling data was used to develop attainable target criteria for Medicine Creek.

The Medicine Creek watershed encompasses approximately 157,860 ha (390,072 acres) and is drained by Medicine Creek (Figure 2). Three TMDL waterbodies, Fate Dam, Brakke Dam and Byre Lake are within the watershed. All three lakes have EPA approved TMDLs. Medicine Creek, (the study area) drains a watershed from approximately Draper, South Dakota to the boundary of Lower Brule Sioux Reservation in Lyman County. The Creek then flows through the reservation and empties into the Missouri River in Lake Sharpe, Lyman County, South Dakota (Figure 2). This portion of Medicine Creek was not in the study area because the State of South Dakota has no jurisdiction on tribal ground and is considered Indian Country as defined in 18 U.S.C. 1151. Thus the TMDL stream segment is from the Lower Brule Reservation Boundary to the highway 83 bridge west of Vivian, South Dakota 121.7 stream kilometers (75.6 stream miles).

Problem Identification

Medicine Creek drains predominantly agricultural land (approximately 60.2 percent cropland and 39.8 percent pastureland) and flows into Medicine Creek. The stream carries sediment (TDS and TSS) and nutrient loads (total nitrogen and total phosphorus), which degrade the water quality of Medicine Creek and ultimately Lake Sharpe reservoir, which may increase eutrophication.

Numeric criteria were violated for TSS based on beneficial use based water quality standards for warmwater marginal fish life propagation water ($\leq$ 263 mg/L). Numeric criteria violations were also recorded for fecal coliform bacteria based on beneficial use based water quality standards for limited contact recreation water ($\leq$ 2,000 cfu/100 ml).

Current watershed conditions (loading) result in a modeled TSS load of 25,225,960 kg/yr (Table 24, Assessment Report page 71) and an average fecal coliform bacteria loading of 4.64×10^{13} cfu/fecal season (Equation 6, Assessment Report page 124). Modeling data indicate that Medicine Creek beneficial use based water quality standards criteria can be met and are realistic and achievable.

Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Medicine Creek has been assigned beneficial uses by the state of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality of rivers, lakes and streams. These criteria must be maintained for the waterbody to satisfy its assigned beneficial uses. Medicine Creek has been assigned four beneficial uses which are listed below:

(6) Warmwater marginal fish life propagation water;
(8) Limited contact recreation water;
(9) Fish and wildlife propagation, recreation and stock watering water and
(10) Irrigation water

Individual parameters determine the support of beneficial uses and compliance with standards. At times, Medicine Creek experiences high sediment, nutrient and fecal coliform loading. Medicine Creek was identified in the 2004 South Dakota Integrated Report for Surface Water Quality Assessment as non-supporting beneficial uses for fish and wildlife propagation, recreation and stock watering water - TDS and irrigation water – conductivity. The 2005 Medicine Creek Watershed Assessment Report also identified two other beneficial use standards as non-supporting, warmwater marginal fish life propagation water – total suspended solids and limited contact recreation water – fecal coliform bacteria.

South Dakota has several applicable narrative standards that may be applied to the undesirable eutrophication of lakes and streams in the state. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life. If adequate numeric criteria are not available, the South Dakota Department of Environment and Natural Resources (SD DENR) uses surrogate measures to assess the trophic status of a lake.

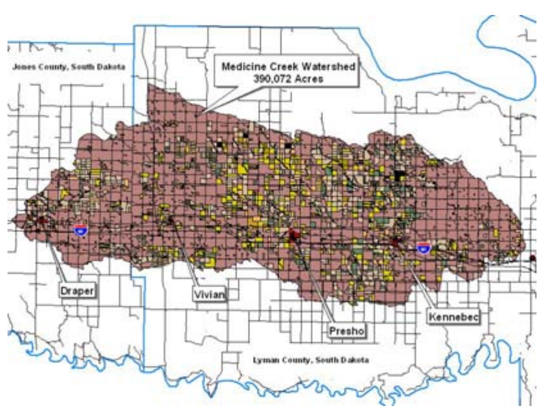

Figure 2. Medicine Creek watershed.

Medicine Creek currently has a modeled annual TSS and fecal coliform bacteria loads of 25,225,960 kg/yr and 4.64 x 10^{13} cfu/fecal season, respectively. Because the majority of the watershed was agricultural, high TSS concentrations and fecal coliform counts were attributed to agriculture and livestock.

Pollutant Assessment

Point Sources

Two towns located in the watershed have wastewater treatment facilities (lagoons); however, they typically do not discharge into Medicine Creek. The Presho facility has a two-cell stabilization pond system followed by an artificial wetland for a total of 10.1 acres for 588 people; while Kennebec has a two-cell stabilization pond system (total of 4 acres) and a population of 284. WLA (Waste Load Allocations) were developed for these facilities (TSS and fecal coliform) to account for loadings if and when circumstances warrant discharge into Medicine Creek.

Nonpoint Sources/Background Sources

Nonpoint/background sources for the Medicine Creek Watershed were estimated using FLUX, assessment and AnnAGNPS modeling.

Under current conditions, the total nonpoint source loadings of total suspended solids from the watershed into Medicine Creek was estimated to be 25,225,960 kg/yr and was attributed to agricultural sources based on FLUX modeling. Nonpoint source/background load allocation of TSS was 20,164,594 kg/yr based on AnnAGNPS modeling.

Nonpoint source loadings for fecal coliform bacteria from the watershed was 4.64 x 10^{13} cfu/fecal season and was attributed to livestock in and around tributaries to and mainstem Medicine Creek. Calculated nonpoint source/background load allocation of fecal coliform bacteria was 3.89 x 10^{13} cfu/fecal season based on EPA TMDL pathogen protocols.

Linkage Analysis

Water quality data were collected from three mainstem monitoring sites within the Medicine Creek watershed. Samples from each site were collected according to South Dakota's Standard Operating Procedures for Field Samplers, Volume I. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected on approximately 10% of the samples according to South Dakota's Non-Point Source Quality Assurance/ Quality Control Plan. Details concerning water-sampling techniques, analysis, and quality control are addressed on pages 8 through 10, page 18 and pages 147 through 150 of the assessment final report.

In addition to water quality monitoring, data was collected to complete a watershed landuse model. The AnnAGNPS model was used to estimate potential sediment and nutrient load reductions from conservation tillage, fertilizer reduction, grazing management and buffer strips within the watershed through the implementation of various BMPs. See the AnnAGNPS final report, Appendix C.

Other BMPs were suggested (streambank stabilization, conversion of highly erodible cropland to rangeland, riparian management) however total suspended solids reduction percentages were not estimated for these BMPs because data was unavailable to calculate viable responses. Sediment and nutrient reductions for these BMPs are incorporated into the TMDL calculation by way of the implicit margin of safety. All estimates were based on conservative percent reductions applied to priority subwatersheds (assessment final report, pages 151 through 158).

Reducing the current TSS load (25,225,960 kg/yr) a minimum of 10.0 percent especially during high flows will reduce the overall annual TSS load to 20,172,490 kg/yr a total reduction of 20.1 percent. The entire load reduction will come from the load allocation portion of the equation. This can be accomplished by implementing modeled and recommended tributary BMPs with an implicit margin-of-safety to support the TMDL target.

Reducing the current average fecal coliform load (4.64 x 10^{13} cfu/fecal season) a minimum of 18.1 percent will reduce the overall seasonal fecal coliform load to 3.89 x 10^{13} cfu/fecal season a total reduction of 16.0 percent. As with TSS, the entire load reduction will come from the load allocation portion of the equation. This can be accomplished by implementing recommended tributary BMPs with an implicit margin-of-safety to support the TMDL target for fecal coliform.

TMDL and Allocations

TMDL

TSS

TSS (kg/year) = 20.1 percent reduction

7,896 kg/yr	(WLA)
+ 20,164,594 kg/yr	(LA)
+ Implicit	(MOS)
20,172,490 kg/yr	(TMDL) [1]

[1] = TMDL Equation implies a 10 percent reduction based on BMP attainability resulting in a 20.1 percent TSS reduction.

Fecal coliform

Fecal coliform cfu/fecal season = 18.3 percent reduction

1.04×10^{12} cfu/fecal season[2]	(WLA)
+ 3.79×10^{13} cfu/fecal season	(LA)
+ Implicit	(MOS)
3.89×10^{13} cfu/fecal season	(TMDL) [1]

[1] = TMDL Equation implies an 18.3 percent reduction of fecal coliform bacteria to realize an overall 16 percent reduction in average fecal coliform loading.
[2] = Fecal Season = May 1 through September 30.

Wasteload Allocations (WLAs)

Presho and Kennebec, South Dakota are located in the watershed and have wastewater treatment facilities (lagoons). WLAs were developed in conjunction with SD DENR Surface Water Quality Program for these facilities (TSS and fecal coliform) to account for loadings if and when circumstances warrant discharge into Medicine Creek. Typically these facilities do not discharge into Medicine Creek, thus no realistic load reductions in TSS and fecal coliform can be expected from WLAs in this watershed. Load reductions needed to meet the TSS and fecal coliform TMDLs are wholly included within the "load allocation" component of the TMDL equation.

Load Allocations (LAs)

TSS

The result of the AnnAGNPS model indicates that grazing management and the conversion of minimum tillage fields to no tillage on select fields/pastures could achieve a 20.1 percent (5,129,140 kg/yr) reduction and increasing the use of buffer strips may achieve a 10.0 percent (2,564,569 kg/yr) reduction in total suspended solids loading to Medicine Creek. This TMDL (20,172,490 kg/year) translates into a 10 percent reduction in the violation rate for TSS (263 mg/L for any one grab sample) and should meet the TSS standard for warmwater marginal fish life propagation waters beneficial use in Medicine Creek.

Fecal Coliform

Assessment data indicate that waste reduction from 1,793 animals is needed to meet the fecal coliform target (Assessment final report, page.124). This translates to a 5.48 percent reduction in the number of animals (1,793) producing an 18.3 percent reduction in average delivered fecal coliform loading based on 2000 through 2004 assessment data.

Waste reduction from 1,793 animals can be achieved through selected tributary BMPs throughout Medicine Creek. Reductions can be realized through a combination of management techniques such as waste management systems, grazing and riparian management, buffer strips and alternate watering sources. A 18.3 percent reduction in delivered fecal coliform load will meet the fecal coliform TMDL target (3.79×10^{13} cfu/fecal season). This TMDL (3.89×10^{13} cfu/fecal season (May 1 through September 30)) translates into a 16 percent reduction in the violation rate for fecal coliform ($\leq$ 2,000 cfu/100 ml for any one grab sample) and should meet the fecal coliform standard for limited contact recreation water beneficial use in Medicine Creek.

Seasonal Variation

Different seasons of the year can yield differences in water quality due to changes in temperature, precipitation and agricultural practices. To determine seasonal differences, Medicine Creek samples were separated into winter (January-March, spring (April-June), summer (July-September) and fall (October-December) seasons. Seasonal concentrations and loads for 2000 through 2001 were calculated through FLUX modeling using parameter specific concentration data. Seasonally, the spring 2001 sampling season had the highest loading for all parameters.

Margin of Safety

All modeled TSS reductions were calculated based on conservative estimations built into the model, while fecal coliform load reductions were calculated using conservative estimations using best professional judgment. Along with conservative modeling, additionally implemented tributary BMP reductions were incorporated into the TMDL calculations in an implicit margin-of-safety (assessment final report, page and 156). Medicine Creek needs a 10.0 percent reduction in TSS loading and an 18.3 percent reduction in fecal coliform loading will meet their respective TMDL targets.

Critical Conditions

Based upon the 2000 through 2001 assessment data, pathogen and sediment loading to Medicine Creek are most severe during the spring (runoff events) and impairments to Medicine Creek are most severe during the late summer and early fall. This is the result of increased loading, violated water quality standards in Medicine Creek.

Follow-Up Monitoring

Medicine Creek is currently on the SD DENR Surface Water Quality Program (SWQP) Water Quality Monitoring site (WQM) for monthly monitoring.

Periodically during the implementation project and once it is completed, monitoring will be necessary to assure that the TMDL has been reached and improvements in average TSI values occur.

Public Participation

During the Medicine Creek watershed Assessment Project, the Medicine Creek watershed assessment project was initiated during the spring of 2000 with EPA Section 319 funds. Medicine Creek is on the priority list of Section 319 Nonpoint Source Pollution Control projects; based on current watershed assessment data Medicine Creek does not support TSS and fecal coliform water quality criteria. American Creek Conservation District agreed to sponsor the project. Federal grant funds totaled $101,796 of which, Medicine Creek was assessed. Funds were used for water quality analyses, equipment, supplies, travel, and wages for the local coordinator. The Lower Brule Sioux Tribe was contacted and invited to attend the final report presentation.

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. American Creek Conservation District Board Meetings (21)
2. County Commission Meetings (2)
3. Individual contact with landowners in the watershed (continuous throughout the project).
4. Articles/surveys/pamphlets sent to landowners in the watershed (5)
5. Newspaper articles (2)
6. Final results presentation (Lower Brule Sioux Tribe invited) (1)
7. Lower Brule Sioux Tribe contact (4)

The findings from these public meetings and comments have been taken into consideration in the development of the Medicine Creek TMDL.

Implementation Plan

As of June of 2005, a four year Medicine Creek implementation project was approved and funded through South Dakota DENR. The American Creek Conservation District is sponsoring the implementation project.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
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Phone 800-227-8917
http://www.epa.gov/region08

August 30, 2006

Ref: 8EPR-EP

Steven M. Pirner, Secretary
Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
Corsica Lake
Medicine Creek
Sheridan Lake
White Lake

Dear Mr. Pirner:

We have completed our review, and have received Endangered Species Act Section 7 concurrence from the U.S. Fish and Wildlife Service, on the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1).

Based on our review, we feel the separate elements of the TMDLs listed in the enclosed table adequately address the pollutants of concern as given in the table, taking into consideration seasonal variation and a margin of safety. In the enclosed table, we have distinguished between TMDLs developed under Section 303(d)(1) *vs.* Section 303(d)(3) of the Clean Water Act. Section 303(d)(1) TMDLs are those for waterbodies that are water quality limited for the pollutant(s) of concern. The determination of whether a particular TMDL is (d)(1) or (d)(3) is made on a waterbody-by-waterbody and pollutant-by-pollutant basis.

Some of the TMDLs designated on the enclosed table as Section 303(d)(1) TMDLs, as distinguished from Section 303(d)(3) TMDLs, may be for waters not found on the current state 303(d) waterbody list. EPA understands that such waters would have been included on the list had the state been aware, at the time the list was compiled, of the information developed in the context of calculating these TMDLs. This information demonstrates that the non-listed water is in fact a water quality limited segment in need of a TMDL. The state need not include these waters that have such TMDLs associated with them on its next Section 303(d) list for the pollutant covered by the TMDL.

Thank you for your submittal. If you have any questions concerning this approval, feel free to contact Vernon Berry of my staff at 303-312-6234.

Sincerely,

Max H. Dodson
Assistant Regional Administrator
Office of Ecosystems Protection and
Remediation

Enclosures

ENCLOSURE 1

APPROVED TMDLS

Waterbody Name*	TMDL Parameter/ Pollutant	Water Quality Goal/Endpoint	TMDL	Section 303(d)1 or 303(d)3 TMDL	Supporting Documentation (not an exhaustive list of supporting documents)
Corsica Lake*	Phosphorous	Maintain a mean annual TSI (N/Chl-*a*/SD) at or below 64.5	5,613 kg/yr total phosphorous (15% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Phase I Watershed Assessment and TMDL Final Report, Corsica Lake, Douglas County, South Dakota (SD DENR, February 2005)
Medicine Creek*	Total Suspended Solids	TSS ≤ 263 mg/L daily maximum	20,172,490 kg/yr TSS (20.1% reduction in average annual TSS loads)	Section 303(d)(1)	■ Phase I Watershed Assessment Final Report and TMDL, Medicine Creek, Lyman and Jones Counties, South Dakota (SD DENR, August 2005)
	Fecal Coliform	Fecal coliform ≤ 2000 cfu/100mL	3.89×10^{13} cfu/fecal season (18.3% reduction in average annual fecal coliform loads)	Section 303(d)(1)	
Sheridan Lake*	Phosphorous	Maintain a mean annual Total Phosphorous TSI at or below 45.0	251 kg/yr total phosphorous (43% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Total Maximum Daily Load Evaluation for Sheridan Lake, Pennington County, South Dakota (SD DENR, May 2006)
White Lake*	Phosphorous	Maintain a mean annual Total Phosphorous TSI at or below 70.0	2,355 kg/yr total phosphorous (30% reduction in average annual total phosphorous loads)	Section 303(d)(1)	■ Watershed Assessment/TMDL Final Report, White Lake, Marshall County, South Dakota (SD DENR, June 2005)
	Dissolved Oxygen	Dissolved oxygen ≥ 5.0 mg/L		Section 303(d)(1)	

* An asterisk indicates the waterbody has been included on the State's Section 303(d) list of waterbodies in need of TMDLs.

APPENDIX H

Public Comments and Responses to Medicine Creek Assessment Report and Total Maximum Daily Load Summary Document

Public Notice Comments:

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Medicine Creek Assessment Final Report**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**November 28, 2005**
Review Date:	**December 28, 2005**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Informal – Public notice**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy
12. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

Criterion Description – Water Quality Impairment Status

TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.

- ☒ Satisfies Criterion
- ☐ Satisfies Criterion. Questions or comments provided below should be considered.
- ☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Medicine Creek is located in the Missouri River Basin, Lyman and Jones Counties, South Dakota. Medicine Creek is listed on South Dakota's 2004 303(d) list as impaired for conductivity and total dissolved solids (TDS) and is ranked as priority 1 (i.e., high priority) for TMDL development. The listed stream segment (US Highway 83 to mouth) is 83.4 miles long and drains a watershed of approximately 390,072 acres. The lower part of the watershed passes through the Lower Brule Indian Reservation before the creek reaches the Missouri River. The Tribal portion of the Medicine Creek watershed was not included in the study area. The predominant landuses in the watershed are cropland (approximately 60.2 percent) and pastureland (approximately 39.8 percent). Thirty eight animal feeding operations are located in the watershed. Assessment data show conductivity and total dissolved solids violated the applicable surface water quality standards. Twenty-one percent of the conductivity samples and nineteen percent of the TDS samples exceeded the daily maximum standard. During the period of assessment it was also determined that the water quality standards are not being met for fecal coliform bacteria and total suspended solids (TSS).

The conductivity and TDS analytical values that exceed the applicable water quality standards seem to occur only at in-stream flows below one cubic foot per second. Therefore, the South Dakota Department of Environment and Natural Resources (SD DENR) is recommending revising the beneficial use standards for irrigation waters and fish and wildlife propagation, recreation and stock watering, and irrigation waters (SD DENR beneficial use categories 9 and 10 respectively). If completed, the water quality standards revision would include a provision that allows the standards to be exceeded at flows below the historic low flows (e.g., 7Q10) as found in Section 74:51:01:30 of the South Dakota administrative rules. The revisions would negate the need for TMDLs for conductivity and TDS if these changes are implemented.

2. Water Quality Standards

Criterion Description – Water Quality Standards

The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

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SUMMARY – The Medicine Creek segment addressed by these TMDLs are impaired by total suspended solids (TSS) and fecal coliform. South Dakota has applicable numeric standards for TSS and fecal coliform that may be applied to this creek segment. The numeric standards being implemented in these TMDLs are: TSS $\leq$ 263 mg/L daily maximum, which is based on the warmwater permanent fish life propagation classification of the creek, and fecal coliform $\leq$ 2000 colonies/100 mL in any one sample (May 1 – Sept 30) which is based on the limited contact recreation classification.

The impairments identified for conductivity and TDS will be addressed either through future water quality standards revisions or future TMDLs.

Other applicable water quality standards are included on pages 23 and 24 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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SUMMARY – Water quality targets for these TMDLs are based on the numeric water quality standards for TSS and fecal coliform. The TMDL includes a TSS target of < 263 mg/L for any one grab sample (20,172,490 kg/yr), and a fecal coliform target of <2000 cfu/100mL in any one grab sample ($3.89x10^{13}$ cfu/fecal season). These targets are based on the warmwater marginal fish life and limited contact recreation beneficial use classifications of the listed Medicine Creek segment. Reduction targets (expressed as percentages) are also specified in the TMDL summaries, and are based on the mean TSS and fecal coliform values derived from the data collected during the period of assessment for the listed segment.

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

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SUMMARY – The TMDL identifies the major sources of TSS and fecal coliform as coming from nonpoint source agricultural landuses within the watershed. These landuses include cropland (approximately 60.2 percent) and pastureland (approximately 39.8 percent), as well as 38 animal feeding operations. Two wastewater treatment facilities (i.e., Presho and Kennebec) are located in the watershed, however they only discharge periodically and are considered to be minor sources.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – The technical analysis addresses the needed TSS and fecal coliform reductions to achieve the desired water quality in the impaired creek segment. The TMDL recommends a 20.1% reduction in average annual TSS loads to Medicine Creek, and an 18.3% reduction in fecal coliform loads.

TMDLs were calculated for Medicine Creek using FLUX, a program developed by the US Army Corps of Engineers, to estimate the hydrologic loads within the watershed. This information was used to calculate the average load of fecal coliform over the fecal season, and to derive export coefficients for TSS to target areas within the watershed with excessive TSS loading.

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting sediment reduction response. The sediment loading source analysis that was used to identify necessary controls in the watershed was based on the identification of targeted or "critical" cells. Cell priority was assigned based on the mean sediment runoff loading. Cells that produce sediment loads greater than two standard deviations over the mean for the watershed were determined to be priority 1, and cells producing loads greater than one but less than 2 standard deviations over the mean were determined to be priority 2. The initial sediment load reductions under this TMDL will be achieved through controls on the priority 1 and 2 critical cells within the watershed.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

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SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, more BMPs were specified than are necessary to meet the targets, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load

TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

- ☒ Satisfies Criterion
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- ☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
- ☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – TMDLs were calculated for TSS and fecal coliform loading into Medicine Creek. The TMDLs recommend an average annual TSS load of 20,172,490 kg/yr (20.1 % reduction), and an average annual fecal coliform load of 3.89×10^{13} cfu/fecal season (from May 1 – Sept 30, 18.3% reduction). The TMDL loads and reductions are based on the "modeled load" which is derived from the concentration data collected during the period of the assessment and the modeled flows from FLUX and AnnAGNPS. The annual loading will vary from year-to-year; therefore, these TMDLs are considered a long term average percent reduction in TSS and fecal coliform loading.

8. Allocation

Criterion Description – Allocation

TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles.

In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

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SUMMARY – These TMDLs address the need to achieve reductions in TSS and fecal coliform to attain water quality standards in the Medicine Creek watersheds. The TMDLs include both "load allocations" and wasteload allocations attributed to nonpoint sources and point sources respectively as specified in the TMDLs. The nonpoint source allocations and the specified reductions of TSS and fecal coliform concentrations can be achieved through the implementation of BMPs including improvements to grazing management practices, conversion of critical cells to no tillage and adding buffer strips.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..

- ☒ Satisfies Criterion
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SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, individual contact with landowners, newspaper articles and a presentation of final results. The Lower Brule Sioux Tribe was contacted during the project period, invited to attend the final report presentation and was mailed a copy of the report during public comment. The draft TMDL was also posted on the State's internet site to solicit comments during the public notice period.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

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SUMMARY – Medicine Creek will continue to be monitored through the DENR surface water quality monitoring program. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

Criterion Description – Restoration Strategy

At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality is not *currently a regulatory requirement, but is considered a value added component of a TMDL document.*

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SUMMARY – The American Creek Conservation District is sponsoring an implementation project for the Medicine Creek watershed. The implementation project was approved and funded through SD DENR in June 2005.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

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SUMMARY – EPA will request ESA Section 7 concurrence from the FWS for these TMDLs.

Enclosure 3

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Medicine Creek Assessment Final Report**
Submitted by:	**Gene Stueven, SD DENR**
Date Received:	**January 19, 2006**
Review Date:	**February 25, 2006**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Formal – Final Approval**

This document provides a standard format for EPA Region 8 to provide comments to the South Dakota Department of Environment and Natural Resources on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
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Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

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SUMMARY – Medicine Creek is located in the Missouri River Basin, Lyman and Jones Counties, South Dakota. Medicine Creek is listed on South Dakota's 2004 303(d) list as impaired for conductivity and total dissolved solids (TDS) and is ranked as priority 1 (i.e., high priority) for TMDL development. The listed stream segment (US Highway 83 to mouth) is 83.4 miles long and drains a watershed of approximately 390,072 acres. The lower part of the watershed passes through the Lower Brule Indian Reservation before the creek reaches the Missouri River. The Tribal portion of the Medicine Creek watershed was not included in the study area and is not included in the TMDL. The predominant landuses in the watershed are cropland (approximately 60.2 percent) and pastureland (approximately 39.8 percent). Thirty eight animal feeding operations are located in the watershed. Assessment data show conductivity and total dissolved solids violated the applicable surface water quality standards. Twenty-one percent of the conductivity samples and nineteen percent of the TDS samples exceeded the daily maximum standard. During the period of assessment it was also determined that the water quality standards are not being met for fecal coliform bacteria and total suspended solids (TSS).

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2. Water Quality Standards

Criterion Description – Water Quality Standards
The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.

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SUMMARY – The Medicine Creek segment addressed by these TMDLs are impaired by total suspended solids (TSS) and fecal coliform. South Dakota has applicable numeric standards for TSS and fecal coliform that may be applied to this creek segment. The numeric standards being implemented in these TMDLs are: TSS $\leq$ 263 mg/L daily maximum, which is based on the warmwater permanent fish life propagation classification of the creek, and fecal coliform $\leq$ 2000 colonies/100 mL in any one sample (May 1 – Sept 30) which is based on the limited contact recreation classification.

The impairments identified for conductivity and TDS will be addressed either through future water quality standards revisions or future TMDLs.

Other applicable water quality standards are included on pages 23 and 24 of the assessment report.

3. Water Quality Targets

Criterion Description – Water Quality Targets
Quantified targets or endpoints must be provided to address each listed pollutant/water body combination. Target values must represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the TMDL target. For pollutants with narrative standards, the narrative standard must be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

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SUMMARY – Water quality targets for these TMDLs are based on the numeric water quality standards for TSS and fecal coliform. The TMDL includes a TSS target of ≤ 263 mg/L for any one grab sample (20,172,490 kg/yr), and a fecal coliform target of ≤ 2000 cfu/100mL in any one grab sample ($3.89x10^{13}$ cfu/fecal season). These targets are based on the warmwater marginal fish life and limited contact recreation beneficial use classifications of the listed Medicine Creek segment. Reduction targets (expressed as percentages) are also specified in the TMDL summaries, and are based on the mean TSS and fecal coliform values derived from the data collected during the period of assessment for the listed segment.

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

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5. Technical Analysis

Criterion Description – Technical Analysis

TMDLs must be supported by an appropriate level of technical analysis. It applies to __all__ of the components of a TMDL document. It is vitally important that the technical basis for __all__ conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.

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SUMMARY – The technical analysis addresses the needed TSS and fecal coliform reductions to achieve the desired water quality in the impaired creek segment. The TMDL recommends a 20.1% reduction in average annual TSS loads to Medicine Creek, and an 18.3% reduction in fecal coliform loads.

TMDLs were calculated for Medicine Creek using FLUX, a program developed by the US Army Corps of Engineers, to estimate the hydrologic loads within the watershed. This information was used to calculate the average load of fecal coliform over the fecal season, and to derive export coefficients for TSS to target areas within the watershed with excessive TSS loading.

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting sediment reduction response. The sediment loading source analysis that was used to identify necessary controls in the watershed was based on the identification of targeted or "critical" cells. Cell priority was assigned based on the mean sediment runoff loading. Cells that produce sediment loads greater than two standard deviations over the mean for the watershed were determined to be priority 1, and cells producing loads greater than one but less than 2 standard deviations over the mean were determined to be priority 2. The initial sediment load reductions under this TMDL will be achieved through controls on the priority 1 and 2 critical cells within the watershed.

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required.

Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – An appropriate margin of safety is included through conservative assumptions in the derivation of the target and in the modeling. Additionally, more BMPs were specified than are necessary to meet the targets, and ongoing monitoring has been proposed to assure water quality goals are achieved. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load
TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – TMDLs were calculated for TSS and fecal coliform loading into Medicine Creek. The TMDLs recommend an average annual TSS load of 20,172,490 kg/yr (20.1 % reduction), and an average annual fecal coliform load of 3.89×10^{13} cfu/fecal season (from May 1 – Sept 30, 18.3% reduction). The TMDL loads and reductions are based on the "modeled load" which is derived from the concentration data collected during the period of the assessment and the modeled flows from FLUX and AnnAGNPS. The annual loading will vary from year-to-year; therefore, these TMDLs are considered a long term average percent reduction in TSS and fecal coliform loading.

8. Allocation

Criterion Description – Allocation
TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles. *In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).*

☒ Satisfies Criterion
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SUMMARY – These TMDLs address the need to achieve reductions in TSS and fecal coliform to attain water quality standards in the Medicine Creek watersheds. The TMDLs include both "load allocations" and "wasteload allocations" attributed to nonpoint sources and point sources respectively as specified in the TMDLs. The nonpoint source allocations and the specified reductions of TSS and fecal coliform concentrations can be achieved through the implementation of BMPs including improvements to grazing management practices, conversion of critical cells to no tillage and adding buffer strips.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA..

☒ Satisfies Criterion
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SUMMARY – The State's submittal includes a summary of the public participation process that has occurred which describes the ways the public has been given an opportunity to be involved in the TMDL development process. In particular, the State has encouraged participation through public meetings in the watershed, individual contact with landowners, newspaper articles and a presentation of final results. The Lower Brule Sioux Tribe was contacted during the project period, invited to attend the final report presentation and was mailed a copy of the report during public comment. The draft TMDL was also posted on the State's internet site to solicit comments during the public notice period.

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

TMDLs may have significant uncertainty associated with selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL documents to articulate the means by which the TMDL will be evaluated in the field, and to provide supplemental data in the future to address any uncertainties that may exist when the document is prepared.

☐ Satisfies Criterion
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☐ Criterión not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – Medicine Creek will continue to be monitored through the DENR surface water quality monitoring program. Post-implementation monitoring will be necessary to assure the TMDL has been reached and maintenance of the beneficial use occurs.

11. Restoration Strategy

Criterion Description – Restoration Strategy
At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document.

☐ Satisfies Criterion
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☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The American Creek Conservation District is sponsoring an implementation project for the Medicine Creek watershed. The implementation project was approved and funded through SD DENR in June 2005.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance
EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
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☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
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SUMMARY – EPA has received ESA Section 7 concurrence from the FWS for these TMDLs.

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